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On the cover:
Shrimp (*Penaeus* sp.).
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Articles *82(1–2), 2020*

The Pacific Halibut, *Hippoglossus stenolepis*, and Sablefish, *Anoplopoma fimbria*, Individual Fishing Quota Program: A Twenty-year Retrospective — *Marysia Szymkowiak, Sarah Marrinan,* and *Stephen Kasperski,* **1**

Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeidae and Rock Shrimp (Sicyoniidae) Fisheries Through Mandatory Observer Coverage, from 2011 to 2016 — *Elizabeth Scott-Denton, Pat F. Cryer, Ben V. Duffin, Matt R. Duffy, Judith P. Gocke, Mike R. Harrelson, Andrew J. Whatley,* and *Jo A. Williams* **17**

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The Pacific Halibut, *Hippoglossus stenolepis,* and Sablefish, *Anoplopoma fimbria,* Individual Fishing Quota Program: A Twenty-year Retrospective

MARYSIA SZYMKOWIAK, SARAH MARRINAN, and STEPHEN KASPERSKI

Introduction

Catch shares are a management tool that have been applied across the world to address overcapitalization in fisheries (Squires et al., 1995; Arnason, 1996; Wilen, 2000). However, there is growing concern that these programs can have adverse and disproportionate impacts on some participants due to the resultant consolidation and loss of access opportunities from high entry costs (Copes and Charles, 2004; Olson, 2011; Grimm et al., 2012). These distributional effects have been shown at the community level as well, with geographic redistributions of fishing privileges and access rights that can lead to losses of employment, income diversification opportunities, tax revenues, and shoreside support businesses and infrastructure (McCay, 1995; Campbell et al., 2000; Copes and Charles, 2004; McCay, 2004; Kasperski and Holland, 2013; Holland and Kasperski, 2016; Holland et al., 2017). Initial distributions, consolidation, and individual fishing quota (IFQ) leasing (of annual pounds), among other factors, may also lead to inter-generational inequities in access and opportunities within and across communities (McCay, 1995; Palsson and Helgason, 1995; McCay, 2004; Pinkerton and Edwards, 2009; Carothers et al., 2010; Carothers, 2015; Carothers[1]).

Recent research indicates that the privatization paradigm of fisheries access in Alaska has created social conflict in communities, transformed the way in which young people perceive participation opportunities, and potentially undermined the sustainability of cultural fishing traditions and economies (Lowe, 2012, 2015; Carothers, 2013; Ringer et al., 2018). This study contributes to the growing body of literature on catch share program effects on the distribution of benefits by examining 20 years of performance of the Pacific halibut and sablefish Individual Fishing Quota Program with respect to its varied spatial and temporal distributional objectives.

The Pacific halibut, *Hippoglossus stenolepis,* and sablefish, *Anoplopoma fimbria,* IFQ Program was implemented in 1995 to address issues associated with the "race for fish" that had resulted from the previous open-access management regime (NPFMC/NMFS, 1992). For the halibut fishery, in the years leading up to the IFQ Program, seasons lasted only a few days in which the commercial sector would harvest their annual catch limits (Pautzke and Oliver[2]). Due to challenges of in-season management in

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[1]Carothers, C. 2008. Privatizing the right to fish: challenges to livelihood and community in Kodiak, Alaska. Univ. Wash. Dissert., 262 p. (avail. at https://anthropology.washington.edu/research/graduate/privatizing-right-fish-challenges-livelihood-and-community-kodiak-alaska).

[2]Pautzke, C., and C. Oliver. 1997. Development of the Individual Fishing Quota Program for sablefish and halibut longline fisheries off Alaska. Natl. Res. Council Committee to Rev. Ind. Fish. Quotas, 4 Sept. 1997, Anchorage, Alaska (avail. at https://www.npfmc.org/ifqpaper/)

ABSTRACT—Although catch shares may be an effective tool to address overcapitalization in fisheries, there is increasing evidence that the costs and benefits of these programs may not be equitably allocated geographically or across generations. This paper examines the spatial and temporal distributional outcomes of 20 years of the Pacific halibut, Hippoglossus stenolepis, *and sablefish,* Anoplopoma fimbria, *Individual Fishing Quota (IFQ) Program, which was implemented with many provisions explicitly intended to mitigate adverse effects on coastal communities, crewmembers, small vessels, and new entrants. Utilizing performance metrics to track distributional objectives over time, we show that, similarly to other catch share programs, the IFQ Program created winners and losers with inter-generational and inter-community inequities in access and opportunities, an effect that may have been exacerbated by regulatory exemptions and loopholes as well as differentiated transportation access in rural Alaska. Nevertheless, some programmatic provisions may have effectively curtailed a complete redistribution of QS (quota shares) within the fleet. Furthermore, consolidation coupled with prolonged fishing seasons and product changes have provided for improvements in some conditions of employment for remaining crew members. We also provide lessons learned for the development and review of catch share programs in the future with respect to defining measureable objectives and establishing mechanisms for data acquisition at the outset. Data collections implemented at the start of a program can provide information to track performance against meaningful baselines. Although potentially time intensive in the development and implementation periods, long-standing data collections may ultimately be easier from the standpoint of the respondents and administrators than ones implemented after a program is in place.*

such a short, competitive season, this sometimes resulted in harvests that exceeded the annual catch limits. Congestion on the grounds led to gear conflicts, lost gear, resource waste, and an incentive to operate with less regard to safety at sea. Short fishing seasons also led to gluts at processing plants and, coupled with what was often hurriedly handled fish, resulted in a mostly frozen product and lower ex-vessel prices for fishermen (NPFMC/NMFS, 2016).

The sablefish fishery had been predominately comprised of foreign vessels until the passage of the Magnuson Fishery Conservation and Management Act in 1976. As domestic operators began to hone their skills in capitalizing on this valuable fishery, it began to look similar to the derby-style conditions of the halibut fishery. For instance, in 1988 the number of active vessels over 50 ft was 10 times greater than in 1982 and the number of smaller active vessels was 14 times greater (Pautzke and Oliver[2]). Similar to the halibut fishery, sablefish season lengths decreased from nearly year-round to only a few weeks in some areas (Oliver, 1997).

Prior to the IFQ Program, the halibut and sablefish fisheries were managed under an open access licensing system (Pautzke and Oliver[2]). As capacity grew rapidly in the halibut fishery in late 1970's and 1980's, and in the sablefish fishery in the late 1980's, the North Pacific Fishery Management Council (NPFMC), which manages Federal fisheries off Alaska (i.e., those from 3 to 200 miles offshore), grappled with limited entry concepts. By the late 1980's, the NPFMC adopted a Statement of Commitment declaring its intent to pursue development of a license limitation or IFQ Program for the sablefish fishery. In 1990, halibut was added to the discussion of alternatives for implementing a license limitation or IFQ Program for the sablefish fishery (NPFMC/NMFS, 2016). In December of 1991, the NPFMC chose an IFQ Program as the preferred management alternative for both halibut and sablefish fixed-gear fisheries. The IFQ Program was approved as a regulatory amendment by the Secretary of Commerce in 1993 and implemented by NMFS in 1995.

In developing the IFQ Program, the NPFMC expressed a desire to end the race for fish and control harvests while balancing a variety of other social and economic objectives, some of which were inherently at odds (NPFMC/NMFS, 1992). The NPFMC wanted to ensure continued access to these fisheries for small vessels and new entrants and to moderate consolidation and the impacts on coastal communities from potential redistributions of quota shares (QS). However, in providing for broad participation, the NPFMC curtailed the harvest capacity reductions and efficiency gains that could have occurred with a less restricted market for QS (Kroetz et al., 2015).

The IFQ Program fundamentally altered prosecution of the North Pacific halibut and sablefish fisheries, starting with the issuance of harvesting privileges. Quota shares are the basic long-term use privilege in the IFQ Program and were issued to participants on the basis of recent pre-IFQ fishing history as a percentage of the QS pool for a species-specific IFQ regulatory area. For both fisheries, these QS are translated into annual IFQ allocations in the form of fishable pounds based on the annual total allowable catches (TAC's) established for each IFQ area. The IFQ's are also vessel class-specific; limiting the length of the vessel upon which they can be fished.

Throughout the lifetime of the IFQ Program, over 70 amendments have modified the management of the halibut and sablefish fisheries. Many of these amendments were in response to distributional impacts that resulted from the program or to better align the benefits of this management regime with the original goals and objectives of the program. These relevant amendments are discussed within the related sections in order to contextualize the results of this study.

After 20 years, the IFQ Program was comprehensively reviewed for the first time by the authors of this study (NPFMC/NMFS, 2016). This paper presents and extends the results of that review with respect to spatial and temporal distributional issues to better understand the changes in the allocations of benefits and costs of the IFQ Program among stakeholder groups (e.g., vessel owners, crewmembers, communities, and the next generation of participants). We focus on these issues because concerns about programmatic inequities informed much of the regulatory structure of the IFQ Program (NPFMC/NMFS, 1992), as well as amendments that were subsequently made to the IFQ Program, and the distributional impacts of catch share programs are an ongoing area of debate in the literature (Ringer et al., 2018; Young et al., 2018).

Specifically, this study examines a number of related distributional issues. How did the IFQ Program perform with respect to reducing capacity while maintaining fleet diversity? Have programmatic provisions intended to provide operational flexibility to IFQ participants affected the owner-operator characteristic of the fleet? How did the shift to IFQ management affect crew employment and fishing opportunities for Alaska coastal communities and new entrants?

This paper is organized as follows: the following section presents the data and methods used in this assessment, including the performance metrics developed to examine the IFQ Program's objectives, as specified by the NPFMC at the time of implementation, and their inherent limitations. This is followed by an in-depth discussion of the study results and the overall conclusions and recommendations for future catch share programs and reviews.

Data and Methods

This study is similar to other retrospective analyses of catch share or limited-access programs, which examine changes in the fishery with respect to the expected or intended impacts of the change in management (Gauvin et al., 1994; Casey et al., 1995; Squires et al., 1995, 1998; Wang, 1995; NRC, 1999; Sutinen, 1999; Hamon et al.,

Table 1.—Performance metrics for IFQ Program distributional objectives.[1]

Objective	Performance metric[2]
Address economic stability in the fisheries and communities	• Fish landing distributions by state
Address rural coastal community development of a small boat fleet	• Fish landing distributions within Alaska, by rural and urban communities
Limit the adjustment cost to current participants including Alaska coastal communities	• Fish landing distributions within rural Alaska communities by transportation access
Maintain the diversity in the fleet with respect to vessel categories	• QS distributions by vessel class • Fleet distribution by vessel class • IFQ landings across vessel classes
Maintain the existing business relationships among vessel owners, crews, and processors	• Crew impacts: N/A (There was no data available to inform a metric; we hosted a focus group workshop with crewmembers to gather qualitative information).
Assure that those directly involved in the fishery benefit from the IFQ Program by assuring that these two fisheries are dominated by owner/operator operations	• Harvest distributions by hired masters and QS holders • Total IFQ leasing
Limit the concentration of QS ownership and IFQ usage that will occur over time	• Gini coefficient and Herfindahl-Hirschman Index of revenues at the vessel level
Provide entry opportunities	• QS distribution by generation (initial recipient vs. new entrant) • Average QS holdings by generation • Rate of new entry

[1]NPFMC established 10 programmatic objectives during the development of the IFQ Program (NPFMC/NMFS, 1992). This study focuses on the programmatic objectives related to distributional impacts of the program, as well as entry opportunities, which was an additional area of concern for the NPFMC during the 20-year review.
[2]All metrics are over time and for both species unless otherwise noted.

2009; Van Putten and Gardner, 2010; Agar et al., 2014; Brinson and Thunberg, 2016). We developed performance metrics (Table 1) around the programmatic objectives that focus on distributional outcomes of the program and examined trends in these metrics to evaluate whether there is indication that the objective is being realized in the IFQ fisheries. Similar to Agar et al. (2014) and Brinson and Thunberg (2016), these performance metrics rely on descriptive statistics such as vessel and QS holder counts, average QS holdings, as well as indices including the Herfindahl-Hirschman index (HHI) and Gini coefficient (Gini, 1936; Herfindahl, 1955; Hirschman, 1964).

We also incorporate locally weighted scatterplot smoothing (LOWESS) in this study, which is a regression technique that places the greatest weight on the nearest neighbor in the data, to expand upon trends observed in the fisheries post-IFQ implementation (Cleveland, 1981). Several data sources were used to construct these performance metrics, including the NMFS harvest and administrative data, Alaska Fisheries Information Network's fisheries landings and community profile data, and Alaska Department of Fish and Game's Commercial Operator's Annual Report processing data.

Information about the number of crewmembers or their earnings has historically not been tracked in the IFQ fisheries. To provide information on IFQ impacts on crewmembers for the review, a focus group workshop was held with IFQ crewmembers. Eighteen key informants (Tremblay, 1957; Krueger and Casey, 2000) attended the focus group, representing various geographic segments of the IFQ fishing fleet, past and present crewmembers, vessel owners, initial QS issuees, and new entrants.

Researchers used process agendas and interview guides to conduct the focus group (Krueger and Casey, 2000), which focused on several key topics including participants' experiences with respect to crew earnings, other conditions of crew jobs (duration of the IFQ fishing season, safety, and overall sense of welfare), and entry opportunities and how these experiences have evolved since the implementation of the IFQ Program. Major themes[3] were developed based on notes taken during the focus group and provided to participants for additional feedback afterwards. Given that no additional information was provided for each topic during or at the end of the focus group or in the follow-up review of the major focus group themes, we were able to determine data saturation, the point at which no new information is being discovered (Corbin and Strauss, 1990; Guest et al., 2006).

The baseline period used throughout this study is the three years preceding the implementation of the IFQ Program, 1992 through 1994, which is presented as an average. Although baseline years could have been defined in a number of different ways and no years would have been completely representative of pre-IFQ Program fisheries, the chosen baseline years were intended to eliminate years with rent-seeking behavior (i.e., irrational increases in participation in the short-run with the long-term goal of establishing a fishing history) and consistent with other analyses of catch share programs undertaken by the National Marine Fisheries Service (Brinson and Thunberg, 2016; Fissel et al., 2017). Since history was determined from activity between 1988 and 1990 and the IFQ Program was identified as the preferred management alternative by the NPFMC in 1991, it is likely there was less strategic fishing behavior in the baseline years chosen. Furthermore, there are concerns about the reliability of the data further back in time.

The performance metrics presented here are only used to examine trends

[3]These major themes are included in the supplementary materials.

in the data related to the distributional policy objectives of the IFQ Program; we do not attempt to make conclusive statements about the progress of the program with respect to these objectives. In addition to data limitations for developing metrics, the objectives themselves are broad, without specified and measurable targets, and sometimes even self-contradictory (e.g., addressing excess harvesting capacity and limiting consolidation).

In addition, the purpose of this study is not to identify causal links between the program and the metric. Causal analysis would necessitate complex, systematic modeling with the ability to control for numerous exogenous influences on the harvesters, processors, markets, and associated communities. It would be inappropriate to assert that changes are uniquely attributable to the program without a counterfactual with which to measure changes against. Instead, this study is focused on describing the tangible changes in the IFQ fisheries with respect to programmatic objectives and provisions, understanding that in addition to the shift in management, there have been other influences on those involved with these fisheries. Throughout this study, we identify these exogenous influences qualitatively when possible.

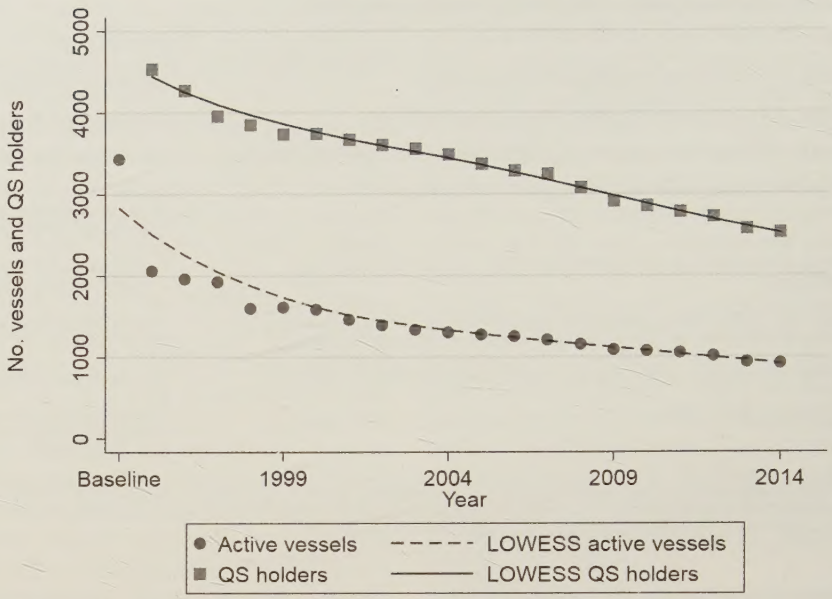

Figure 1.—Annual active vessels and total QS holders in the halibut IFQ fishery from 1992 to 2014 with locally weighted scatterplot smoothing curves.

Results and Discussion

The following section presents the findings organized by groupings of programmatic provisions and objectives around topic areas associated with temporal and spatial distributional issues, examining key facets of IFQ outcomes related to the NPFMC's concerns about potential inequities.

Harvesting Capacity, Revenue Distribution, and Market Concentration

Many of the benefits of the IFQ Program were expected to arise from resulting reductions in harvesting capacity and longer fishing seasons (NPFMC/NMFS, 1992). Under the program, fishing seasons extended from just a few days in some cases to over 8 months. Researchers have shown that catch share programs can be an effective tool for reducing capacity in fisheries and prolonging fishing seasons (Hilborn et al., 2001; Dupont et al., 2002, 2005; Brinson and Thunberg, 2016; Birkenbach et al., 2017). For example, fewer participating vessels and longer seasons could reduce competition on fishing grounds and gear conflicts, improve safety, reduce bycatch and discarding, etc. Given that capacity can be directly related to fleet size, the number of active vessels (those making landings of IFQ fish) was used as a proxy for capacity (Brinson and Thunberg, 2016). The number of QS holders (calculated at the beginning of each fishing year) over time is also included to provide information on consolidation of ownership.

Examination of the LOWESS curves in Figures 1 and 2 indicates that there was substantial consolidation in the IFQ fisheries at both the QS holder and vessel level immediately following the implementation of the IFQ Program with consolidation continuing over the course of the program, although generally at a slower rate. From IFQ implementation to 2014, there was a 73% reduction in vessels in the halibut fishery and a 67% reduction in sablefish vessels; concurrently, there was a 44% reduction in halibut QS holders and a 21% reduction in sablefish QS holders. Differentiated attrition rates by fishery may be attributed to distinct amounts of consolidation at the start of the program as well as differing incentives (TAC's, ex-vessel prices, opportunity costs, etc.), with indication that many of these vessels were displaced into other fisheries (Kroetz et al., 2019). These trends, along with data on the number of quota shareholders per vessel over time (NPFMC/NMFS, 2016), indicate that since IFQ implementation quota shareholders have increasingly been coordinating the harvest of their IFQ on fewer vessels. Reductions in available IFQ due to decreasing TAC's, especially over the last 10 years, may also be incentivizing shareholders to pool their quota to make economically worthwhile fishing trips.

The NPFMC sought to balance a decrease in harvesting capacity with continued opportunities for a diverse fleet, which in turn was intended to limit programmatic impacts on fisheries participants and Alaska coastal com-

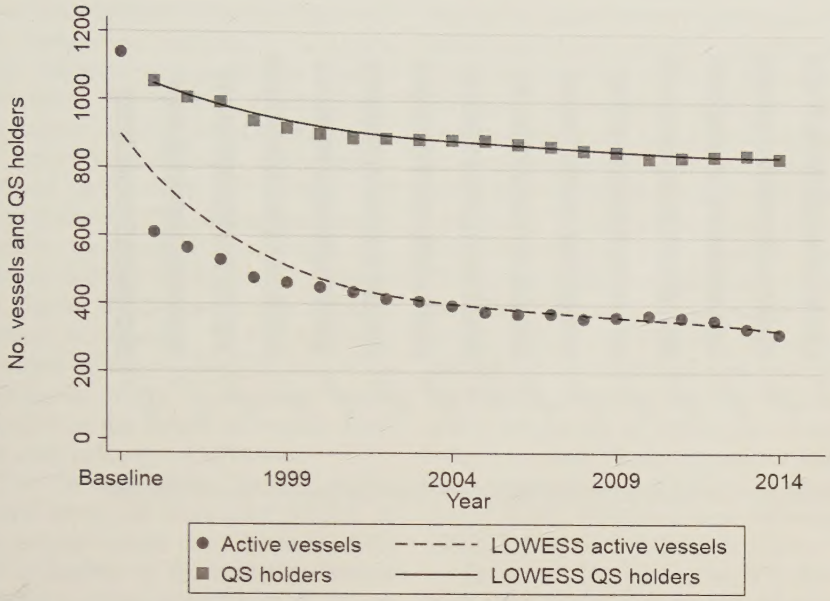

Figure 2.—Annual active vessels and total QS holders in the sablefish IFQ fishery from 1992 to 2014 with locally weighted scatterplot smoothing curves.

munities (NPFMC/NMFS, 1992). To prevent excessive consolidation, QS holders have a cap on the percent of the QS pool they can hold (QS ownership cap) and vessels are capped at the amount they can harvest each year (vessel IFQ cap). Similar to other catch share program evaluations, we used the Gini coefficient (Gini, 1936) and the Herfindahl-Hirschman Indices (HHI) (Herfindahl, 1955; Hirschman, 1964) to examine changes in the distribution of annual IFQ revenue across all active vessels within both IFQ fisheries (Agar et al., 2014; Brinson and Thunberg, 2016).

The Gini coefficient varies between 0 and 1, where a value of 0 indicates that all vessels earn exactly the same gross revenue, while a value of 1 indicates that a single vessel earns 100% of the gross revenues. The absolute value of the Gini coefficient is less important than its trend over time, with a decreasing trend indicating greater evenness of revenue across vessels and an increasing trend indicating a less even distribution of revenues. The Gini coefficients in the pre- and post-IFQ periods imply different patterns for the two fisheries (Fig. 3, 4).

In the halibut fishery there has been an increase in revenue concentration since IFQ implementation, which started below 0.60, and has been above that level for the duration of the program, even while declining from 2011 to 2014. In the sablefish fishery there has been a more even revenue distribution since IFQ's following the first several years wherein inequality increased. The sablefish fishery includes both catcher-processors (those vessels which both catch and process that catch onboard) and catcher vessels that catch and deliver to shoreside processors. While the Gini coefficient for sablefish catcher-processor vessels only shows a lot more variation throughout the years (partially due to the smaller number of participating vessels in this group), it has also been below the pre-IFQ baseline value throughout the course of the IFQ Program indicating a more even distribution.

HHI scores approach zero when a market is composed of a large number of vessels of similar size and reaches a maximum of 10,000 when a single vessel controls the entire market. Federal merger guidelines indicate that HHI scores of less than 1,500 indicate a lack of market concentration and an unlikely presence of adverse competitive effects while scores above 2,500 indicate highly concentrated markets (USDOJ and FTC, 2010).

For both IFQ fisheries, the HHI indicates increasing revenue concentration following IFQ implementation (Fig. 5, 6), likely in part due to the decrease in the number of participating vessels following IFQ implementation. In the sablefish IFQ fishery, the HHI for catcher vessels only and for all vessels combined (inclusive of both catcher vessels and catcher-processors) indicates a steep increase in revenue concentration the year following implementation of the program and a gradual increase for several years afterwards, followed by general stability since the early 2000's.

The HHI for sablefish catcher-processors operates on a vastly different scale than the HHI for catcher vessels due to the higher concentration of revenues over a smaller number of vessels amongst catcher-processors. However, this sector also experienced an increase in concentration of sablefish IFQ revenues throughout the course of the program, reaching a high of nearly 1,400 in 2014. The catcher processor sablefish revenues in Alaska only represent a segment of the whole sablefish market, which also includes sablefish that are supplied by Canada and the U.S. west coast as well as catcher vessels in Alaska, which would be considered in any formal review of market concentration.

Variation in the trends demonstrated by the HHI and Gini coefficient can be attributed to them measuring slightly different things. Whereas the Gini coefficient is a metric of inequality measuring the evenness of revenue distribution per vessel, the HHI is a metric of market power evaluating revenue concentration over the total number of vessels.

One of the primary intentions of the IFQ Program was to address overcapacity in the fisheries; thus, consolidation was a desired programmatic outcome. However, the extent of that intended capacity reduction was not

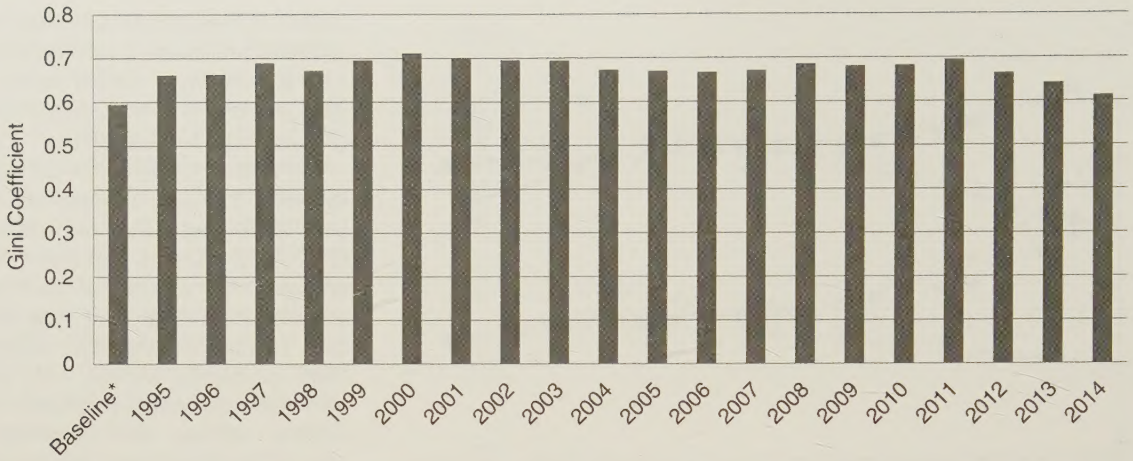

Figure 3.—Halibut IFQ fishery Gini coefficient for vessel revenue distributions from the baseline period (the average for 1992 through 1994) to 2014.

articulated and the exit of a substantial segment of the fleet and QS holders has invariably changed who benefits from these fisheries and by how much.

Fleet Diversity

One of the areas of concern with increasing consolidation following IFQ implementation was the potential redistribution of QS towards the owners and operators of larger vessels, many of which were presumed to operate more efficiently than the smaller vessels and could thereby have a greater willingness to pay for QS (Casey et al., 1995). The NPFMC, however, wanted to maintain fleet diversity under the IFQ Program, providing for continued participation of larger vessels while ensuring access for small vessels which were disproportionately owned by Alaskans and assumed to be the entry point for new participants (NPFMC/NMFS, 1992).

Therefore, since implementation, the program has included QS vessel class designations by vessel length and prohibitions on QS trading between the vessel-classes (Holland et al., 2015; Sanchirico et al.[4]). While consolidation has occurred in all vessel length categories, the proportion of active vessels participating in the halibut IFQ fleet that falls into the smallest length category (<35 ft length overall (LOA)) has slightly decreased from 38% during the baseline period to an average of 35% over the course of the program. The proportional composition of the fleet in the largest length category (>60 ft LOA) has remained stable at an average of 8% while the mid-size class (35–60 ft LOA) has increased from 56% to an average of 57% since IFQ. Overall, a diverse fleet has continued to operate in the halibut IFQ fishery as was intended by these provisions. The sablefish IFQ fleet was composed of generally mid-size vessels (35–60 ft LOA) and vessels in the largest length category (>60 ft LOA) pre-IFQ program. The proportional composition of active vessels has remained relatively stable throughout the program for the sablefish IFQ fishery.

After program implementation, it was determined the QS class categories were not needed in order to pre-

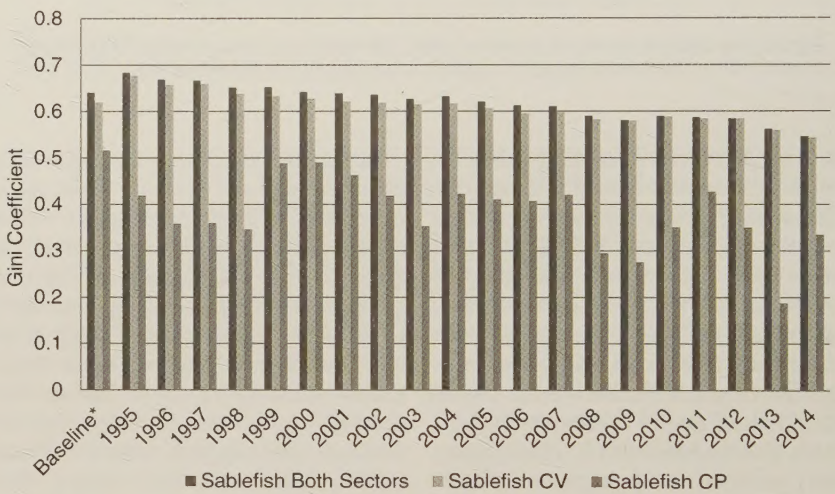

Figure 4.—Sablefish IFQ fishery Gini coefficients for vessel revenue distributions by catcher vessel and catcher processor sector and for both sectors combined from the baseline period (the average for 1992 through 1994) to 2014.

[4]Sanchirico, J. N., K. Kroetz, and D. K. Lew. 2011. Memorandum: preliminary analysis of the Alaskan halibut and sablefish ITQ markets. Final report to NMFS.

serve participation from the larger vessel categories (NPFMC[5]; NMFS[6]); thus, subsequent amendments created allowances for "fishing down" (landing larger vessel class QS on smaller vessels). Additional amendments allowed for "fishing up" halibut IFQ in portions of the Bering Sea, using smaller vessel class QS on larger vessels, to address safety concerns about mandating small vessels fish in these waters. In response to the flexibility afforded by these fishing up and down provisions, there have been some changes in the length of vessels landing each category of QS class.

Due to the ability for QS to be fished down, an increasing portion of the largest vessel class (>60 ft LOA) QS is landed on the mid-size vessels (35–60 ft LOA), accounting for on average 33% and 32% of the halibut and sablefish largest class QS, respectively, over the course of the program. In the halibut IFQ fishery, the implementation of the "fishing up" amendments (in 2007 and 2014) were also followed by a redistribution of IFQ landings towards the mid-size vessels. Thus, despite substantial consolidation and increasing revenue concentration following IFQ, programmatic provisions curtailed QS redistributions across vessel length categories, evidenced by changes in fleet landing patterns following a lift in inter-class IFQ harvest restrictions.

Absenteeism and Changing Operational Paradigms

One of NPFMC's key objectives for the IFQ Program was to ensure that the benefits of the IFQ fisheries flowed to those actively participating, including Alaska coastal communities (NPFMC/NMFS, 1992). Researchers have shown that leasing of harvesting privileges can provide greater flexibility and economic efficiency gains above what can be expected with permanent transferability alone (Palsson and Helgason, 1995; LeGallic and Mongruel, 2006; van Putten and Gardner, 2010; Moxnes, 2012; Sanchirico et al.[7]; Wilen and Brown[8]). However, leasing can be associated with prohibitively high QS prices for new entrants and a migration of fishing privileges away from historically dependent fishing communities (LeGallic and Mongruel, 2006; Pinkerton and Edwards, 2009; Stewart and Callagher, 2011).

To curtail leasing in the IFQ fisheries, the NPFMC included an owner-on-board mandate for individual catcher vessel QS holders and an overall prohibition on leasing of catcher vessel IFQ (NPFMC/NMFS, 1992). In general, initial recipients including both individuals and non-individual entities were exempted from the owner-on-board mandate and may use hired masters (anyone designated by the shareholder) to land their catcher vessel IFQ. Because some catcher vessel QS recipients had used hired masters in the halibut and sablefish fisheries prior to the IFQ Program, the NPFMC intended the exemption to provide initial recipients with the latitude to continue in these business practices (NPFMC/NMFS, 2016).

Hired master use for catcher vessel IFQ has increased since program implementation despite a continued transfer of QS to individuals from non-individual entities; and, programmatic amendments intended to reduce reliance on hired masters have only begun to show any evidence of success over the last several years (Szymkowiak and Himes-Cornell, 2015; Szymkowiak and Felthoven, 2016). The IFQ Program tied the hired master use privilege to the initial QS holder and not the initially allocated QS. Thus, it allowed initial recipients to build business models on the basis of utilizing hired masters to land their IFQ and created the opportunity for hired master use to increase in the fisheries. In 1995 hired masters harvested 13% of the total weight of IFQ halibut. This proportion peaked at 46% of the total weight of IFQ halibut in 2010 and decreased to 38% in 2014. For the sablefish fishery, the percent of the total weight of sablefish harvested by hired masters increased from 12% in 1995 to 55% in 2014 (NPFMC/NMFS, 2016).[9]

Although hired master-shareholder relationships can be de facto leasing arrangements (Szymkowiak and Himes-Cornell, 2015), they are not considered as such in the IFQ Program and the only allowable mechanisms for catcher vessel IFQ leasing are under emergency conditions or rare circumstances (military, survivorship, and medical leasing, as well as leasing to the recreational sector, and leasing to community development groups in times of low abundance). Total leasing of catcher vessel IFQ comprises a small percentage of the TAC's in both IFQ fisheries (about 4.25% and 2% in 2015 in the halibut and sablefish fisheries, respectively), although these percentages have also been increasing over the last 15 years (NPFMC/NMFS, 2016). Furthermore, there is indication of repeated use of the medical lease provision for catcher vessel IFQ by a limited number of QS holders in the fisheries, which may be indicative of them using the provision to bypass the owner-on-board requirement or for chronic conditions from which shareholders may not recover (NPFMC/NMFS, 2016).

[5]NPFMC. 1996. Draft for secretarial review: Environmental assessment and regulatory impact review/initial regulatory flexibility analysis for categories (class D & D). N. Pac. Fish. Manage. Counc., Anchorage, Alaska (avail. at https://alaskafisheries.noaa.gov/sites/default/files/analyses/bsai42goa42ea.pdf).

[6]National Marine Fisheries Service (NMFS). 2005. Draft for NOAA Fisheries Service Review: Regulatory impact review and initial regulatory flexibility analysis for seven proposed amendments to regulations that implement the halibut and sablefish IFQ Program. Juneau, AK. 9 November, 2005 (avail. at: https://alaskafisheries.noaa.gov/sites/default/files/analyses/rir_irfa_61506.pdf).

[7]Sanchirico, J., R. Newell, and K. Papps. 2005. Asset pricing in created markets for fishing quotas. Discuss. Pap. dp-05-46, Resour. for the Future.

[8]Wilen, J., and G. Brown. 2000. Implications of various transfer and cap policies in the halibut charter fishery. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., AFSC Rep., 33 p. (avail. at https://www.st.nmfs.noaa.gov/st5/RecEcon/Publications/Halibut_1st_with_graphs.pdf).

[9]The hired master harvest numbers for halibut are slightly different here than what is presented in the IFQ review (NPFMC/NMFS, 2016) due to the incorrect inclusion of harvests for the Community Development Quota groups in the review in Areas 4B, 4C, and 4D in the IFQ review.

The IFQ Program does not include a systematic collection of lease rates (the percent of the ex-vessel revenue that goes to the QS holder) or the distribution of revenues within arrangements between hired masters and quota shareholders. However, lease rates are self-reported by some participants on the forms required by NMFS for medical and beneficiary leases in the IFQ Program, accounting for about 10% of all lease transactions.[10] Based on these transactions, over the course of the program, average lease rates reported have been between 51% and 56% of ex-vessel revenues. Previous research on revenue distributions between shareholders and hired masters also indicates about 50–60% of revenues go to the shareholder for the harvest of their IFQ (Szymkowiak and Himes-Cornell, 2015). This means that lessees or hired masters earn 40–50% of the gross ex-vessel revenues, from which they will deduct operating costs, crew shares, etc. Although lease rates should reflect annual earnings expectations in the IFQ fisheries (Holland et al., 2015), in situations where fishermen's profits are squeezed by rising lease rates, there is evidence that this can contribute to poor safety decisions and high-grading (van Putten and Gardner, 2010; Emery et al., 2014a, b; Szymkowiak and Felthoven, 2016).

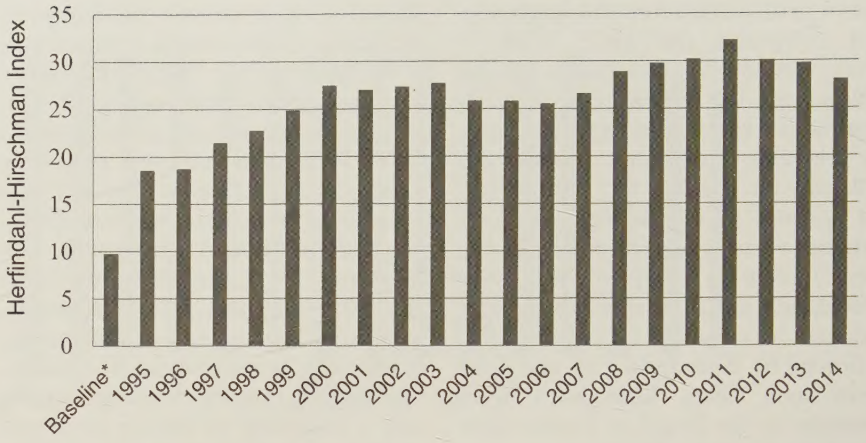

Figure 5.—Halibut IFQ fishery HHI scores for vessel revenue distributions from the baseline period (the average for 1992 through 1994) to 2014.

Even as QS is transferred to second-generation shareholders who are mandated to be on board during the harvest of their IFQ, there is anecdotal information that some of these second-generation shareholders are coming on-board as "walk-ons" or "rideons" who do not participate in the actual fishing activity but fulfill the letter of the law by being on board during the harvesting of their IFQ (Van der Voo, 2013; Szymkowiak and Himes-Cornell, 2015). As these are de facto leasing relationships, the flow of benefits from the halibut and sablefish fisheries may not strictly be to those actively participating even with the exit of initial recipients (Szymkowiak and Himes-Cornell, 2015).

Intergenerational Equity and Entry Opportunities

In an overcapitalized fishery, the transition to catch shares is expected

[10]The lease rates are noted as a source of financing for the transfer and written in as a percentage of the gross revenue, and many of these reported lease rates are not independent observations.

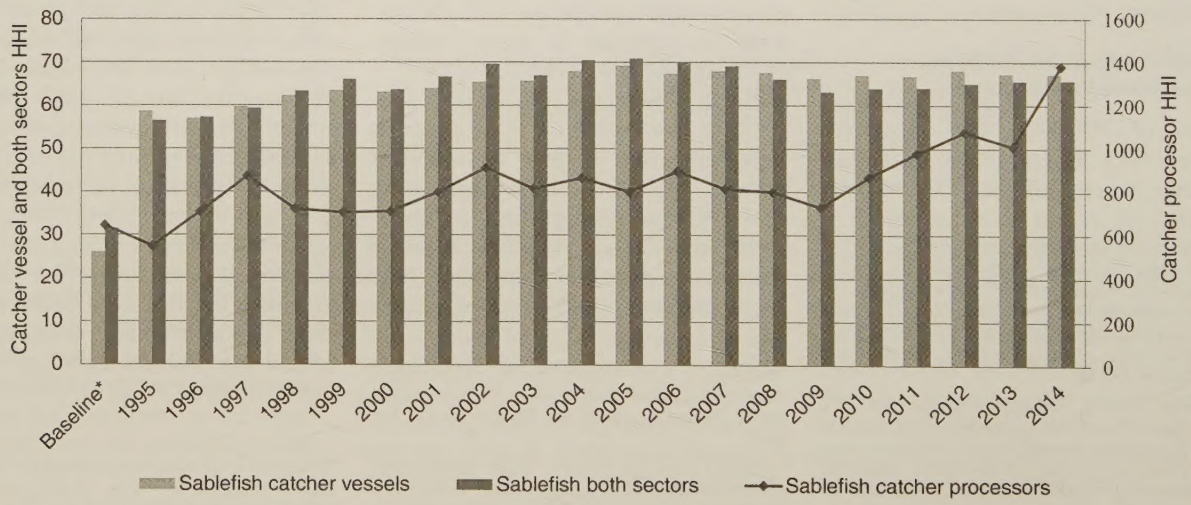

Figure 6.—Sablefish IFQ fishery HHI scores for catcher vessels, catcher-processor, and both sectors combined vessel revenue distributions from the baseline period (the average for 1992 through 1994) to 2014.

to reduce employment opportunities and create other adjustment costs, especially for crew (OECD, 2000). Since the implementation of the IFQ Program, the transition of QS to inactive shareholders, consolidation, and QS pooling have altered crew employment opportunities despite an IFQ programmatic objective to minimize these impacts (NPFMC/NMFS, 1992). The total number of crew jobs in the IFQ fisheries has likely decreased by several thousand (Hartley and Fina, 2001), due to overall consolidation as well as QS pooling and a reduced number of crew positions per boat resulting from the slower fishery (Casey et al., 1995).

With a decline in the number of available crew jobs, IFQ crew workshop participants also noted that the bargaining strength of crewmembers relative to vessel owners has decreased and, in turn, so have crew shares—the percentage of gross ex-vessel revenues that crewmembers receive. However, focus group participants also reported that, similarly to other catch share fisheries (Abbott et al., 2010), average seasonal crew earnings became more predictable and generally increased under IFQ's as average vessel revenues increased. Participants noted a perception of safety improvement in the fisheries as well because of the flexibility to choose fishing days and avoid bad weather, developing relatively consistent work schedules, and sleeping more while at sea, as well as reduced congestion on fishing grounds and the reduced need to haul gear as quickly as possible (Knapp, 1997; Carothers, 2013).[11]

Unless otherwise addressed, inequities in the generational distribution of catch share benefits may be inherent to this type of management regime. When an IFQ system gives rise to resource rents and QS are freely allocated to initial recipients with no mechanism for collecting some of this rent by resource managers, most of the resource rent may be captured by the first generation of quota shareholders when they exit and sell their shares and that value is paid by the incoming shareholders (Whitmarsh, 1998). Furthermore, the acquisition of QS is fundamentally different for initial recipients and new entrant QS holders. Initial recipients may utilize their initially allocated QS as collateral for loans or subsidize the purchase of additional QS through revenues generated from harvest of IFQ derived from initially allocated QS; opportunities that do not exist for new entrants.

In developing the IFQ Program, the NPFMC wanted to ensure that future participants in these fisheries were active fishermen. Therefore, it restricted QS acquisition to those who were initial recipients and those individuals that can demonstrate 150 days of crewing experience in any U.S. commercial fishery. Nevertheless, many of the trends already discussed for these fisheries that stemmed from other programmatic objectives or provisions would be associated with adverse effects on the availability of opportunities for new entrants including the transition of QS to inactive shareholders, consolidation, the (slightly) increasing proportion of larger class vessels, and the decreasing numbers of crew employment opportunities (NPFMC/NMFS, 2016).

We examine entry opportunities with respect to QS distribution by generation (initial recipient or new entrant—defined as any person who purchased QS in a given year and did not hold any QS in any previous year in either of the IFQ fisheries), average QS holdings by generation, and the rate of new entry (examined as the number of new entrants relative to all other QS holders in the fishery). Whereas the first two metrics provide information on how the fisheries have been transitioning to ownership by a new generation of participants, the third metric indicates perceptions of opportunities in the fisheries for new participants.

New entrants' QS holdings have been incrementally increasing since the start of the IFQ Program. Since 2009 and 2010 for the halibut and sablefish IFQ fisheries, respectively, new entrants hold the majority of QS, with 56% and 53% of the respective holdings (NPFMC/NMFS, 2016). However, there continues to be a large disparity in the amount of QS held by generation; in 2015, an individual initial recipients' average QS holdings were 21% and 55% greater than new entrant's QS holdings in the halibut and sablefish fisheries, respectively (NPFMC/NMFS, 2016).

There is indication that barriers to entry into the IFQ fisheries have changed over the 20 years of the IFQ Program. According to IFQ crew focus group participants, over the last decade decreasing TAC's, increasing QS prices, and rising operating costs associated with regulatory requirements have made entry more difficult. This is aligned with theoretical expectations and previous research indicating that as catch share programs reduce overcapacity and increase efficiency, the costs of QS rise and may become cost prohibitive for new entrants who often lack sufficient access to capital (Huppert et al., 1996; Dewees et al., 1998; Copes and Charles, 2004; Pinkerton and Edwards, 2009; Cardwell and Gear, 2013; Carothers[1]). Figure 7 shows that average QS prices (in 2014 dollars per pound of associated IFQ) in both IFQ fisheries have increased substantially since the early to mid-2000's.

The NMFS Fisheries Finance Program was established in 1996 in part to provide financing for QS in the halibut and sablefish IFQ fisheries. According to IFQ participants and QS loan agents interviewed for the IFQ Program Review, fisheries income diversification and collateral has become increasingly important as a means for new entrants to build up capital to buy QS and for lenders concerned about the health of the IFQ stocks. At the same time participation in alternative fisheries has become increasingly constrained by other limited entry programs (Kasperski and Holland, 2013; Holland and Kasperski, 2016), making it difficult for participants to meet requirements

[11] As part of the IFQ Review, NIOSH conducted a safety assessment of the IFQ fleets and concluded that although there has likely been some decrease in hazards as a result of IFQ's, fatalities have continued in the fisheries (NPFMC/NMFS, 2016).

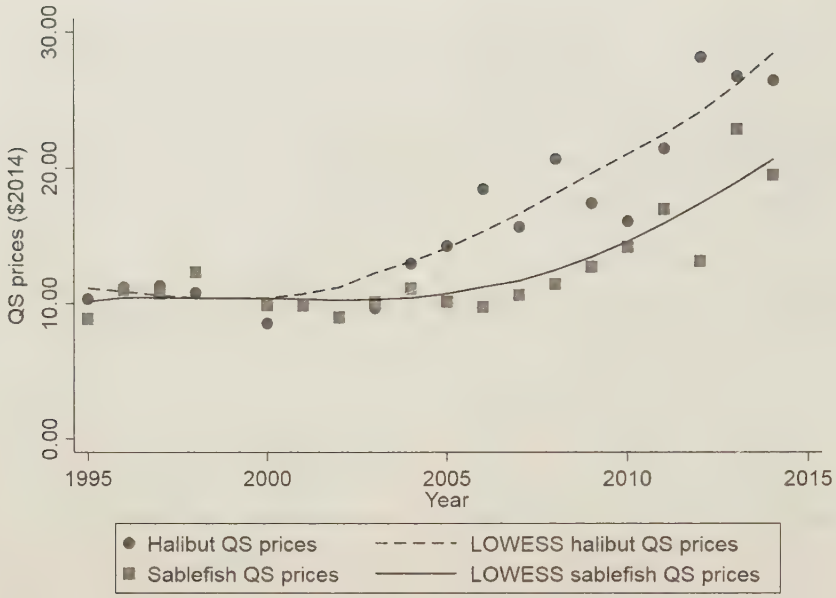

Figure 7.—Average halibut and sablefish QS prices from 1995 to 2014 with locally weighted scatterplot smoothing curves.

to qualify for loans. Holland et al. (2017) find that species diversification decreased after the implementation of the IFQ Program across all halibut and sablefish vessels (although they found no statistically significant difference in the coefficient of variations in vessel revenues before and after IFQ Program implementation for those that still participate in the fishery or for those that exited the IFQ fishery and fished other species). Consistent with expectations about these impacts from the literature and previous experience with catch share programs, the trend in the rate of new entrants (the number of new entrants as a percent of total quota shareholders) over the course of the IFQ Program (Fig. 8) demonstrates a considerable decrease in entry trends over the last 20 years.

Fishing Communities

One of the consequences of the derby-style halibut and sablefish fisheries prior to IFQ's, was over-capitalization in the processing sector (Matulich and Clark, 2003; Fell and Haynie, 2011). The switch to IFQ management was expected to slow the pace of the fisheries and gradually change the product form for halibut, as had happened following individual vessel quotas (IVQ's) in the British Columbia halibut fishery several years prior (Casey et al., 1995; Herrmann, 1996; Grafton et al., 2000).

These anticipated changes were expected to result in some geographic redistributions of IFQ landings from outside of Alaska into Alaska and among Alaska coastal communities to those with access to transportation, which would be critical in moving fresh product to markets (NPFMC/NMFS, 1992). There was also concern that the program could lead to a redistribution of QS ownership within Alaska away from rural Alaska communities.

As previously noted, to address these concerns, the NPFMC included several provisions to ensure the continued participation of Alaska coastal communities in the IFQ Program, including QS allocations by vessel class, limits on who can acquire and use QS, limits on leasing and hired master use, QS acquisition and IFQ use caps, and also through allocating a portion of the Bering Sea and Aleutian Islands (BSAI) halibut and sablefish TAC's to communities in the Bering Sea as part of the Community Development Quota (CDQ) Program.[12]

Since IFQ implementation, Alaska halibut has gradually increased in fresh production, averaging 48% fresh product from 1995 to 2014 (and 60% in 2013 and 2014) compared to 20% during the 1992 to 1994 baseline period (NPFMC/NMFS, 2016). Whereas the primary market for halibut is North America, sablefish is primarily processed for export to Japan (AFSC, 2016) and sablefish product forms largely did not change following IFQ implementation (NPFMC/NMFS, 2016). However, there is considerable overlap between the vessels that prosecute these fisheries, so changes in landing patterns for halibut affected sablefish landings as well. The IFQ Program in essence released some of the previous constraints and operational requirements associated with processing in the IFQ fisheries and allowed new processors without the capital investment in frozen processing capacity to enter the market. However, this also diminished the competitive advantage of some that had been processing these fisheries prior to IFQ and had previously invested in capital that was no longer necessary for the new market (Matulich and Clark, 2003; Fell and Haynie, 2011, 2013).

The decline of processors in these fisheries has been substantial, with 90% of the processors that had been processing halibut or sablefish pre-IFQ no longer participating in these fisheries (NMPFC/NMFS, 2016).[13] As other researchers have noted, pro-

[12]The CDQ Program was created by the NPFMC in 1992 to provide Western Alaskan communities with the opportunity to participate in federally-managed BSAI fisheries through harvest allocations. Given the highly capitalized nature of these fisheries direct harvesting opportunities for residents in these communities have been largely constrained to halibut due to its proximity to shore (Szymkowiak and Himes-Cornell, 2018).

[13]There are some general limitations to the underlying data used to examine processor entry and exit. The data is self-reported and any new buyer, including a previous processor that opened a plant in a different port or those that bought fish strictly for the purpose of transporting the fish to market, would qualify as a processor in this dataset.

cessor exit from the IFQ fisheries was also a function of trends in other fisheries in which the processor operated, poor business administration, and other personal circumstances (Dawson, 2006). The absence of a fish buyer in a community can contribute to QS selling decisions and thus adversely affect the capacity of a community to sustain participation (Szymkowiak et al., 2019).

Previous research on community impacts from the IFQ Program has explored the out-migration of QS from communities on the Alaska Peninsula subgroup (Tingley et al., 1998), participation in the QS market as explained by QS holder residency (Carothers et al., 2010), and impacts on traditional cultures and the social fabric of communities, crewmember empowerment, and entry opportunities (Carothers 2008, 2015; Carothers et al., 2010). In general, rural residents received relatively small initial QS allocations, likely had lower profit margins, were more susceptible to inter-annual variability in income due to limited employment opportunities, and had less access to capital to purchase additional QS (Carothers et al., 2010; Sethi et al., 2012; Sethi et al., 2014a,b; McDowell Group[14]).

Evidence of a decrease in participation in the halibut and sablefish fisheries by small and remote Gulf of Alaska communities following IFQ implementation precipitated the development of the Community Quota Entity Program in 2004, which allows for QS purchase by non-profit entities in these communities as a way to increase their participation (NPFMC, 2010). However, the program has had limited success in terms of inducing participation because the high costs of entry remain prohibitive for many communities (Carothers, 2011; NPFMC, 2010).

We examine changes in QS holdings and IFQ landings at the aggregated state level (Alaska, Washington, Oregon, and all other states) and the aggregated Alaska community level (rural and urban). Here, rural is defined as a community with fewer than 2,500 people, based on the U.S. Census Bureau definition. Rural communities are further decomposed on the basis of transportation access (road and airport access).

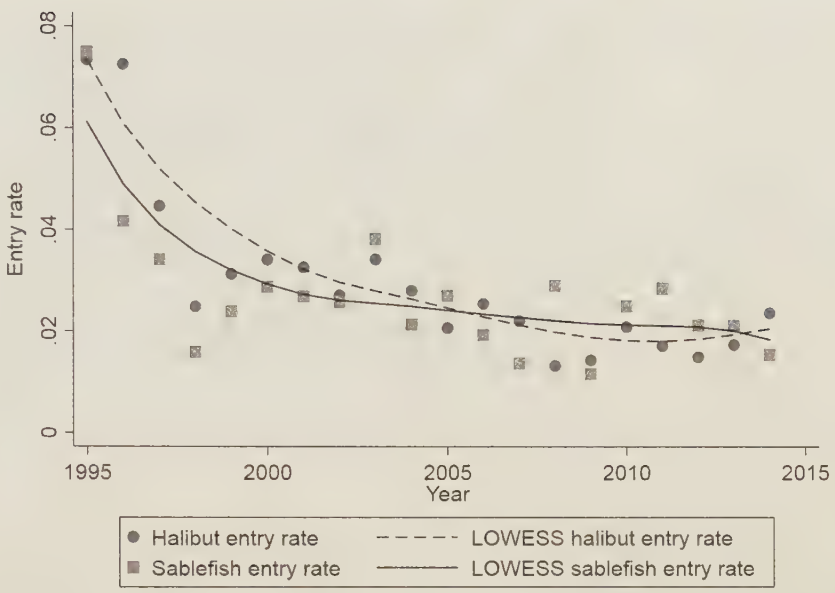

Figure 8.—Halibut and sablefish IFQ entry rates from 1995 to 2014 with locally weighted scatterplot smoothing curves.

From IFQ implementation to 2014, the percentage of total IFQ landed pounds at Alaska shoreside processors has increased from 92% to 97% for halibut and from 99% to 100% for sablefish (NPFMC/NMFS, 2016). Concomitantly, there has been a shift of halibut and sablefish IFQ landings from remote communities (without airports or access to the road system) to those with airport access. Since the late 2000's, those communities without connections to the road system or commercial flights have had nearly no halibut or sablefish landings, decreasing from about 25% for halibut and 45% for sablefish during the baseline years (NPFMC/NMFS, 2016).

Since IFQ implementation, the proportion of QS held by Alaskans has been stable, decreased slightly for QS holders from Washington, remained stable for QS holders from Oregon, and increased slightly for QS holders in other states. Of the total QS held by Alaskans, the percentage held by those in rural Alaska has remained relatively stable since initial QS allocations, increasing by 3% for halibut QS and decreasing by 2% for sablefish QS from 1995 to 2015. Similarly to the changes in IFQ landings among rural Alaska communities, there has been a general movement of QS for both IFQ fisheries away from the more remote communities (without airport and road access) to those with transportation access (Fig. 9, 10). Because we did not hold the communities constant in the time series, the divergence in these figures in the trends in 2013 is due to a community being designated as rural due to a population decrease for a single year below the 2,500 cutoff. Expanding upon these findings, research also indicates that residency in a remote Alaska community is a significant contributor to the probability of selling halibut QS, even when accounting for various other community, individual, and QS characteristics (Szymkowiak et al., 2019). In addition to overall consolidation trends, the movement of processing capacity out

[14]McDowell Group. 2005. Community quota entity financial analysis, prepared for Southeast Alaska Inter-tribal Fish and Wildlife Commission.

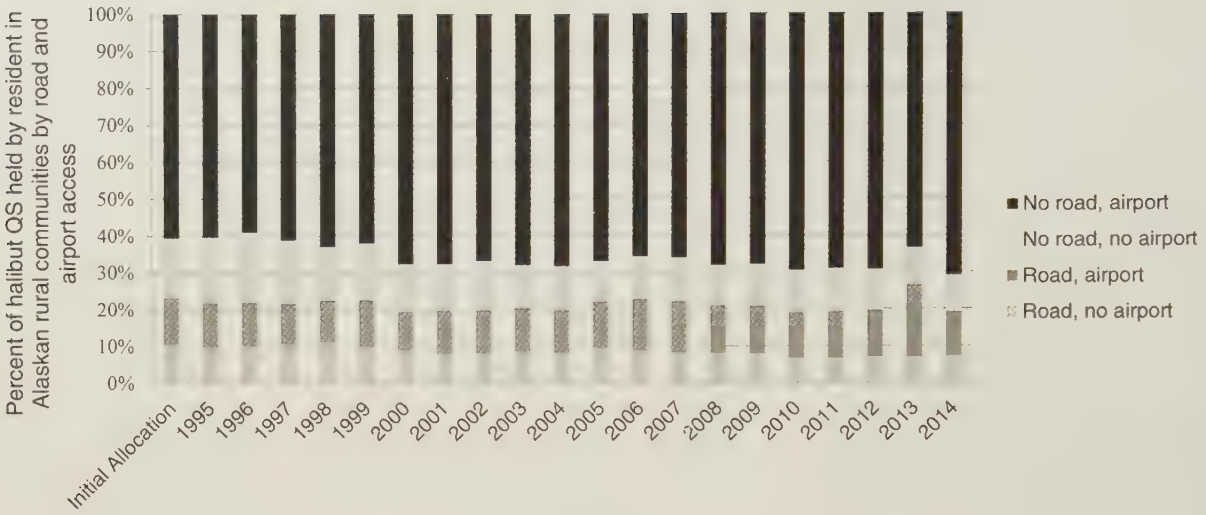

Figure 9.—Percent of halibut QS held by rural Alaska residents by community transportation access.

of some remote rural Alaska communities potentially created spillover impacts on availability of support services and on fuel prices, impacting operating costs for IFQ fishermen in these communities and how competitive they could be in the market for QS.

Conclusions

As intended at its outset, the Pacific halibut and sablefish IFQ Program provided for decreased harvesting and processing capacity in the IFQ fisheries and the elimination of the previous derby fishing conditions. However, similar to other catch share programs, the IFQ Program created winners and losers in terms of the temporal and spatial distribution of outcomes. This occurred despite many and varied provisions intended to limit adverse impacts on participants, which may not demonstrate the flaws of the provisions themselves but the difficulty of balancing objectives, such as harvesting and processing capacity reductions while also providing fleet, stakeholder, and community protections. Our ability to understand the effects of the program across these various distributional layers was constrained by the use of secondary data sources some of which were highly limited in temporal scope and representativeness. Future extensions of this research could reasonably warrant a primary data collection effort for each of these distributional effects and a mixed-methods approach that integrates ethnographic research to understand how impacts reverberate throughout communities.

Nevertheless the IFQ Program does offer a number of lessons specific to how programmatic provisions have related to policy outcomes for some distributional objectives. As previously noted by Szymkowiak and Himes-Cornell (2017), regulatory exemptions for initial recipients with respect to the owner-on-board mandate created a decades-long lag in the transition to an owner-operator IFQ fleet while regulatory loopholes in leasing provisions may allow for continued absenteeism. If lessees are stretched in their capacity to make a profit harvesting others' IFQ's, there may be long-term negative implications for the sustainability of the resource and safety of the fleet.

Despite limits on consolidation, QS trading and leasing, and who can participate in the IFQ fisheries, QS prices have risen considerably over the two decades of the IFQ Program and entry has decreased considerably. Although this was not systematically examined in this study, high QS prices may be tied to the continued exploitation of some IFQ regulatory exemptions and loopholes, but may also be associated with diminishing diversification opportunities for Alaska fishermen more broadly. Coupled with decreasing crew employment opportunities in the IFQ fisheries due to consolidation and increases in lease rates, high QS prices have made entry into the IFQ fisheries prohibitive for many individuals. However, some conditions of crew employment have also likely improved, including perceptions of safety, average earnings, and predictability of the latter. Thus the availability of crew jobs and upward mobility may have been adversely affected while the type of job that IFQ crew have may have improved.

There is also indication that some of the provisions of the IFQ Program were effective at curtailing a complete redistribution of QS within the fleet, but less so when examining QS transfer patterns at the community level in Alaska. Quota share allocations by vessel class and trading prohibitions provided for fixed QS distributions, but changes in the fleet composition over time do indicate that the diversity of the fleet would have likely changed

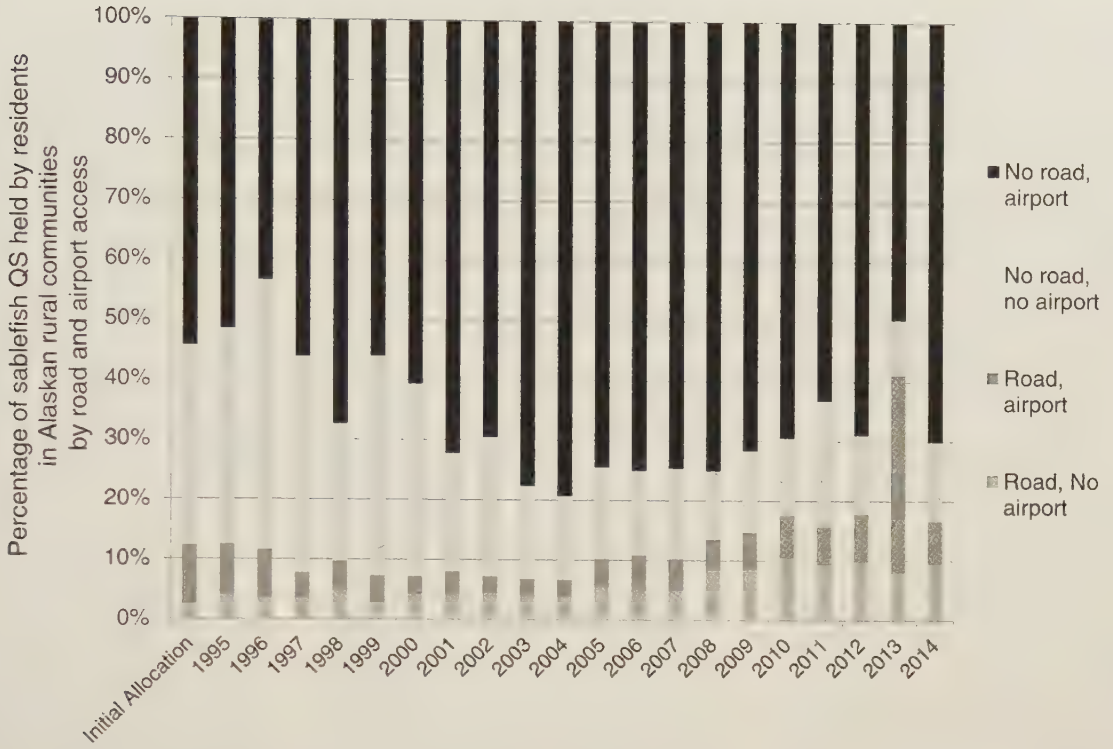

Figure 10.—Percent of sablefish QS held by rural Alaska residents by community transportation access.

given further regulatory flexibility. At the community level, however, there are demonstrable losses of QS from remote Alaska communities, many of which were likely associated with product form changes which necessitated transportation access, as shown in this study and that of Szymkowiak et al. (2019). Thus, although maintaining opportunities for the smallest vessel class in the IFQ fisheries was envisioned as a mechanism of protecting Alaska coastal communities, it did not effectively curtail QS transfers out of the most remote communities, which may have been associated with product form changes and the loss of buyers, as well as broader social dynamics and changes in other fisheries that would not have been easily addressed with regulatory provisions simply in the IFQ Program.

The IFQ Program also offers a number of lessons for catch share program design and review. Clear, measurable targets or objectives should be determined at the outset of a new management program so that the program may be evaluated in a meaningful way. For example, the NPFMC wanted to address excess harvesting capacity in the fixed gear halibut and sablefish fisheries, but it did not define excess or a level of desired capacity in the IFQ fisheries. As others have also noted, baselines and methodologies for programmatic evaluations should also be pre-determined, and readily understood metrics should be supplemented with rigorous analytical methods (Agar et al., 2014). Measurable targets would also facilitate evaluating a program that has contradictory objectives, like addressing excess harvesting capacity while limiting consolidation and maintaining fleet diversity. Progress toward addressing excess harvesting capacity would inherently result in consolidation, potential reductions in fleet diversity, and challenges for entry. Determining metrics and targets for these objectives at program development would have made the concurrent attainment of these objectives feasible rather than inherently contradictory.

Finally, complementary to measurable targets is the necessity for regulatory agencies to have the mechanisms to gather, validate, and store the appropriate data to track performance metrics. Some of the IFQ programmatic objectives related to distributional impacts lacked the data to design an appropriate metric to evaluate performance. For example, lack of any data on crew members in the IFQ fisheries precluded a systematic examination of IFQ impacts on crew employment in terms of number of jobs, duration/seasonality, earnings, upward mobility, etc. The fisheries also lack any cost and effort data for examining net returns or rent or data on lease rates to determine net benefits to participants or the nation. Data collections implemented prior to the development of a program can provide information

to systematically track performance against stated objectives using relevant baseline periods. Furthermore, although such initial data collection programs may be time intensive at the beginning, there is likely to be less work associated with maintaining long-standing data collections from both the respondents' and an administrative standpoint, which has been demonstrated in the Economic Data Collection Program implemented as part of the west coast groundfish trawl rationalization program (Steiner[15]).

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Literature Cited

Abbott, J. K., B. Garber-Yonts, and J. E. Wilen. 2010. Employment and remuneration effects of IFQs in the Bering Sea/Aleutian Islands crab fisheries. Mar. Resour. Econ. 25(4):333–354 (doi: https://doi.org/10.5950/0738-1360-25.4.333).

Agar, J. J., J. A. Stephen, A. Strelcheck, and A. Diagne. 2014. The Gulf of Mexico red snapper IFQ program: the first five years. Mar. Resour. Econ. 29(2):177–198 (doi: https://doi.org/10.1086/676825).

AFSC (Alaska Fisheries Science Center). 2016. Wholesale market profiles for Alaska groundfish and crab fisheries. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Alaska Fish. Sci. Cent., 134 p. (avail. at https://archive.fisheries.noaa.gov/afsc/News/pdfs/Wholesale_Market_Profiles_for_Alaskan_Groundfish_and_Crab_Fisheries.pdf).

Arnason, R. 1996. On the ITQ fisheries management system in Iceland. Rev. Fish Bio. Fish. 6(1):63–90 (doi: https://doi.org/10.1007/BF00058520).

Birkenbach, A. M., D. J. Kaczan, and M. D. Smith. 2017. Catch shares slow the race to fish. Nature 544(7649) 223 (doi: https://doi.org/10.1038/nature21728).

Brinson, A., and E. Thunberg. 2016. Performance of federally managed catch share fisheries in the United States. Fish. Res. 179:213–223 (doi: https://doi.org/10.1016/j.fishres.2016.03.008).

Campbell, D., D. Brown, and T. Battaglene. 2000. Individual transferable catch quotas: Australian experience in the southern bluefin tuna fishery. Mar. Pol. 24:109–117 (doi: https://doi.org/10.1016/S0308-597X(99)00017-2).

Cardwell, E., and R. Gear. 2013. Transferable quotas, efficiency and crew ownership in Whalsay, Shetland. Mar. Pol. 40:160–166.

Carothers, C. 2008. Privatizing the right to fish: challenges to livelihood and community in Kodiak, Alaska. Univ. Wash. Dissert., 262 p. (avail. online at https://anthropology.washington.edu/research/graduate/privatizing-right-fish-challenges-livelihood-and-community-kodiak-alaska).

Carothers, C. 2011. Equity and access to fishing rights: exploring the community quota program in the Gulf of Alaska. Human Organ. 70:213–223 (doi: https://doi.org/10.17730/humo.70.3.d686u2r7j2267055).

_____. 2013. A survey of US halibut IFQ holders: Market participation, attitudes, and impacts. Mar. Pol. 38:515–522 (doi: https://doi.org/10.1016/j.marpol.2012.08.007).

_____. 2015. Fisheries privatization, social transitions, and well-being in Kodiak, Alaska. Mar. Pol. 61:313–322 (doi: https://doi.org/10.1016/j.marpol.2014.11.019).

_____, D. K. Lew, and J. Sepez. 2010. Fishing rights and small communities: Alaska halibut IFQ transfer patterns. Ocean Coast. Manage. 53(9):518–523 (doi: https://doi.org/10.1016/j.ocecoaman.2010.04.014).

Casey, K. E., C. M. Dewees, B. R. Turris, and J. E. Wilen. 1995. The effects of individual vessel quotas in the British Columbia halibut fishery. Mar. Resour. Econ. 10(3):211–230 (doi: https://doi.org/10.1086/mre.10.3.42629588).

Cleveland, W. S. 1981. LOWESS: A program for smoothing scatterplots by robust locally weighted regression. Am. Stat. 35(1):54.

Copes, P., and A. Charles. 2004. Socioeconomics of individual transferable quotas and community based fishery management. Agric. Resour. Econ. Rev. 33(2):171–181 (doi: https://doi.org/10.22004/ag.econ.31263).

Corbin, J. M., and A. Strauss. 1990. Grounded theory research: Procedures, canons, and evaluative criteria. Qual. Sociol. 13(1):3–21 (doi: https://doi.org/10.1007/BF00988593).

Dawson, R. 2006. Vertical integration in the post-IFQ halibut fishery. Mar. Pol. 30(4):341–346 (doi: https://doi.org/10.1016/j.marpol.2005.04.001).

Dewees, C. M. 1998. Effects of individual quota systems on New Zealand and British Columbia fisheries. Ecol. Appl. 8(sp1):S133–S138 (doi: https://doi.org/10.2307/2641371).

Dupont, D. P., R. Q. Grafton, J. Kirkley, and D. Squires. 2002. Capacity utilization and excess capacity in multi-product privatized fisheries. Resour. Energy Econ. 24:193–210.

_____, K. J. Fox, D. V. Gordon, and R. Q. Grafton. 2005. Profit and price effects of multispecies individual transferable quotas. J. Agric. Econ. 56:31–57.

Emery, T. J., K. Hartmann, B. S. Green, C. Gardner, and J. Tidsell. 2014a. Does 'race for fish' behavior emerge in an individual transferable quota fishery when the total allowable catch becomes non-binding. Fish Fish. 15:151–169.

_____, _____, _____, _____, and _____. 2014b. Fishing for revenue: how leasing quota can be hazardous to your health. ICES J. Mar. Sci. 71:1854–1865.

Fell, H., and A. Haynie. 2011. Estimating time-varying bargaining power: a fishery application. Econ. Inquiry 49(3):685–696.

_____ and _____. 2013. Spatial competition with changing market institutions. J. Appl. Econ. 28 (4):702–719.

Fissel, B., M. Dalton, B. Garber-Yonts, A. Haynie, S. Kasperski, J. Lee, D. Lew, A. Lavoie, C. Seung, K. Sparks, and S. Wise. 2017. Stock assessment and fishery evaluation report for the groundfish fisheries of the Gulf of Alaska and Bering Sea/Aleutian Island Area: economic status of the groundfish fisheries off Alaska, 2016. N. Pac. Fish. Manage. Counc., Econ. Stat. Rep. (http://www.afsc.noaa.gov/refm/docs/2017/economic.pdf).

Gauvin, J. R., J. M. Ward and E. E. Burgess. 1994. Description and evaluation of the wreckfish (*Polyprion americanus*) fishery under individual transferable quotas. Mar. Resour. Econ. 9(2):99–118.

Gini, C. 1936. On the measure of concentration with special reference to income and statistics. Colo. Coll. Publ., Gen. Ser. 208:73–79.

Grafton, R. G., D. Squires, and K. J. Fox. 2000. Private property and economic efficiency: a study of common-pool resource. J. Law Econ. 43:679–713.

Grimm, D., I. Barkhorn, D. Festa, K. Bonzon, J. Boomhower, V. Hovland, and J. Blau. 2012. Assessing catch shares' effects evidence from Federal United States and associated British Columbian fisheries. Mar. Pol. 36(3):644–657.

Guest, G., A. Bunce, and L. Johnson. 2006. How many interviews are enough? An experiment with data saturation and variability. Field Methods 18(1):59–82.

Hamon, K. G., O. Thébaud, S. Frusher. and L. R. Little. 2009. A retrospective analysis of the effects of adopting individual transferable quotas in the Tasmanian red rock lobster, *Jasus edwardsii*, fishery. Aquat. Living Resour. 22(4):549–558.

Hartley, M., and M. Fina. 2001. Changes in fleet capacity following the introduction of individual vessel quotas in the Alaskan Pacific halibut and sablefish fishery. FAO Fish. Tech. Pap. 412:186–207.

Herfindahl, O. C. 1955. Comment on Rosenbluth's measures of concentration. *In* G. Stigler (Editor), Business concentration and price policy, p. 95–99. Princeton Univ. Press, Princeton, N.J.

Herrmann, M. 1996. Estimating the induced price increase for Canadian Pacific halibut with the introduction of the individual vessel quota program. Can. J. Agric. Econ. 44(2):151–164.

Hilborn R., J. J. Maguire, A. M. Parma, and A. A. Rosenberg. 2001. The precautionary approach and risk management: can they in-

[15]Steiner, E. 2016. Economic data collection program administration and operations report. Northwest Fisheries Science Center (avail. at https://www.nwfsc.noaa.gov/research/divisions/fram/documents/Administration_Operation_Report_October_2016.pdf).

crease the probability of successes in fishery. Can. J. Fish. Aquat. Sci. 58(1):99–107.
Hirschman, A. O. 1964. The paternity of an index. Am. Econ. Rev. 54(5):761–762.
Holland, D. S., and S. Kasperski. 2016. The impact of access restrictions on fishery income diversification of U.S. West Coast fishermen. Coast. Manage. 44(5):452–463.
_____, E. Thunberg, J. Agar, S. Crosson, C. Demarest, S. Kasperski, L. Perruso, E. Steiner, J. Stephen, A. Strelcheck, and M. Travis. 2015. U.S. catch share markets: a review of data availability and impediments to transparent markets. Mar. Pol. 57:103–110.
_____, C. Speir, J. Agar, S. Crosson, G. DePiper, S. Kasperski, A. W. Kitts, and L. Perruso. 2017. Impact of catch shares on diversification of fishers' income and risk. Proc. Natl. Acad. Sci. 114(35):9,302–9,307.
Huppert, D. D., G. M. Ellis, and B. Noble. 1996. Do permit prices reflect the discounted value of fishing? Evidence from Alaska's commercial salmon fisheries. Can. J. Fish. Aquat. Sci. 53(4):761–768.
Kasperski, S., and D. S. Holland. 2013. Income diversification and risk for fishermen. Proc. Natl. Acad. Sci. 110(6):2,076–2,081.
Knapp, G. 1997. Initial effects of the Alaska halibut IFQ program: survey comments of Alaska fishermen. Mar. Resour. Econ. 12(3):239–248.
Kroetz, K., J. N. Sanchirico, and D. K. Lew. 2015. Efficiency costs of social objectives in tradable permit programs. J. Assoc. Environ. Resour. Econ. 2(3):339–366.
_____, M. N. Reimer, J. N. Sanchirico, D. K. Lew, and J. Huetteman. 2019. Defining the economic scope for ecosystem-based fishery management. Proc. Natl. Acad. Sci. 116(10):4,188–4,193.
Krueger, R. A., and M. A. Casey. 2000. Focus groups: a practical guide for applied research. Sage Publ., Inc., 280 p.
Le Gallic, B., and R. Mongruel. 2006. Slipper skippers and absentee landlord: examining social and economic implications of resource privatisation. *In* A. L. Shriver (Compiler), Proceedings of the Thirteenth Biennial Conference of the International Institute of Fisheries Economics & Trade, July 11–14, 2006, Portsmouth, UK: Rebuilding Fisheries in an Uncertain Environment. Int. Inst. Fish. Econ. Trade, Corvallis, Oreg. (avail. at https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/gf06g3830).
Lowe, M. E. 2012. Alaska coastal community youth and the future. Rep. Prep. for Alaska Sea Grant Coll. Prog., Inst. Soc. Econ. Res., Anchorage, 80 p.
_____. 2015. Localized practices and globalized futures: challenges for Alaska coastal community youth. Marit. Stud. 14(1):1–25 (doi: https://doi.org/10.1186/s40152-015-0024-y).
Matulich, S. C., and M. L. Clark. 2003. North Pacific halibut and sablefish IFQ policy design: quantifying the impacts on processors. Mar. Resour. Econ. 18:149–166.
McCay, B. 1995. Social and ecological implications of ITQs: an overview. Ocean Coast. Manage. 28(1–3):3–22 (doi: https://doi.org/10.1016/0964-5691(96)00002-6).
_____. 2004. ITQs and community: an essay on environmental guidance. Agric. Resour. Econ. Rev. 33(2):162–170 (doi: https://doi.org/10.1017/S1068280500005748).
Moxnes, E. 2012. Individual transferable quotas versus auctioned seasonal quotas: an experimental investigation. Mar. Pol. 36:339–349 (doi: https://doi.org/10.1016/j.marpol.2011.07.003).
NRC. 1999. Sharing the fish: toward a national policy on individual fishing quotas. Natl. Res. Counc., Natl. Acad. Press, Wash., D.C., 436 p. (doi: https://doi.org/10.17226/6335).
NPFMC. 2010. Review of the Community Quota Entity (CQE) Program under the Halibut/Sablefish IFQ Program. N. Pac. Fish. Manage. Counc., Anchorage, AK, Final Rep., 39 p. (avail. at https://www.npfmc.org/wp-content/PDFdocuments/halibut/CQEreport210.pdf).
NPFMC/NMFS. 1992. Final supplemental environmental impact statement/environmental impact statement for the individual fishing quota management alternative for fixed gear sablefish and halibut fisheries: Gulf of Alaska and Bering Sea Aleutian Islands. N. Pac. Fish. Manage. Counc., Natl. Mar. Fish. Serv., Anchorage, AK, 599 p. (avail. at https://www.fisheries.noaa.gov/resource/document/final-supplemental-environmental-impact-statement-environmental-impact).
_____. 2016. Twenty-year review of the Pacific halibut and sablefish Individual Fishing Quota Management Program. N. Pac. Fish. Manage. Counc., Anchorage, AK, 474 p. (avail. at https://www.npfmc.org/wp-content/PDFdocuments/halibut/IFQProgramReview_417.pdf).
Oliver, C. W. 1997. The evolution of sablefish, *Anaplopoma fimbria*, fisheries management off Alaska: from open access to IFQ's. *In* M. E. Wilkins and M. W. Sanders (Editors), Biology and management of sablefish *Anoplopoma fimbria*, p. 239–245. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 130, 275 p.
Olson, J. 2011. Understanding and contextualizing social impacts from the privatization of fisheries: an overview. Ocean Coast. Manage. 54(5):353–363 (doi: https://doi.org/10.1016/j.ocecoaman.2011.02.002).
OECD. 2000. Transition to responsible fisheries: economic and policy implications. Organ. Econ. Coop. Develop., Paris, France (doi: https://doi.org/10.1787/9789264188020-en).
Palsson, G., and A. Helgason. 1995. Figuring fish and measuring men: the individual transferable quota system in the Icelandic cod fishery. Ocean Coast. Manage. 28:117–146 (doi: https://doi.org/10.1016/0964-5691(95)00041-0).
Pinkerton, E., and D. Edwards. 2009. The elephant in the room: the hidden costs of leasing individual transferable fishing quotas. Mar. Pol. 33:707–713 (doi: https://doi.org/10.1016/j.marpol.2009.02.004).
Ringer, D., C. Carothers, R. Donkersloot, J. Coleman, and P. Cullenberg. 2018. For generations to come? The privatization paradigm and shifting social baselines in Kodiak, Alaska's commercial fisheries. Mar. Pol. 98:97–103 (doi: https://doi.org/10.1016/j.marpol.2018.09.009).
Sethi, S. A., M. Dalton, and R. Hilborn. 2012. Quantitative risk measures applied to Alaskan commercial fisheries. Can. J. Fish. Aquat. Sci. 69(3):487–498 (doi: https://doi.org/10.1139/f2011-170).
_____, M. Reimer, and G. Knapp. 2014a. Alaskan fishing community revenues and the stabilizing role of fishing portfolios. Mar. Pol. 48:134–141 (doi: https://doi.org/10.1016/j.marpol.2014.03.027).
_____, W. Riggs, and G. Knapp. 2014b. Metrics to monitor the status of fishing communities: An Alaska state of the state retrospective 1980–2010. Ocean Coast. Manage. 88:21–30 (doi: https://doi.org/10.1016/j.ocecoaman.2013.11.007).
Squires, D., J. Kirkley, and C. A. Tisdell. 1995. Individual transferable quotas as a fisheries management tool. Rev. Fish. Sci. 3(2):141–169 (doi: https://doi.org/10.1080/10641269509388570).
_____, H. Campbell, S. Cunningham, C. Dewees, R. Q. Grafton, S. F. Herrick, J. Kirkley, S. Pascoe, K. Salvanes, B. Shallard, and B. Turris. 1998. Individual transferable quotas in multispecies fisheries. Mar. Pol. 22(2):135–159 (doi: https://doi.org/10.1016/S0308-597X(97)00039-0).
Stewart, J., and P. Callagher. 2011. Quota concentration in the New Zealand fishery: annual catch entitlement and the small fisher. Mar. Pol. 35:631–646 (doi: https://doi.org/10.1016/j.marpol.2011.02.003).
Sutinen, J. G. 1999. What works well and why: evidence from fishery-management experiences in OECD countries. ICES J. Mar. Sci. 56(6):1,051–1,058 (doi: https://doi.org/10.1006/jmsc.1999.0551).
Szymkowiak, M., and R. Felthoven. 2016. Understanding the determinants of hired skipper use in the Alaska halibut IFQ fishery. N. Am. J. Fish. Manage. 36(5):1,139–1,148 (doi: https://doi.org/10.1080/02755947.2016.1184201).
_____ and A. Himes-Cornell. 2015. Towards individual-owned and owner-operated fleets in the Alaska halibut and sablefish IFQ program. Maritime Stud. 14(1):1–19 (doi: https://doi.org/10.1186/s40152-015-0037-6).
_____ and _____. 2017. Do active participation measures help fishermen retain fishing privileges? Coast. Manage. 45(1):56–72 (doi: https://doi.org/10.1080/08920753.2017.1237243).
_____ and _____. 2018. Fisheries allocations for socioeconomic development: Lessons learned from the Western Alaska Community Development Quota (CDQ) program. Ocean Coast. Manage. 155:40–49 (doi: https://doi.org/10.1016/j.ocecoaman.2018.01.014).
_____, S. Kasperski, and D. Lew. 2019. Identifying community risk factor for quota share loss. Ocean Coast. Manage. 178:104851 (doi: https://doi.org/10.1016/j.ocecoaman.2019.104851).
Tingley, A., E. Dinneford, and K. Iverson. 1998. Changes in the distribution of Alaska's commercial fisheries entry permits, 1975 to 1997. Alaska Commer. Fish. Entry Commiss., CFEC Rep. 98-5N, 444 p. (avail. at https://www.cfec.state.ak.us/RESEARCH/18-2N/CFEC%2018-02N.pdf).
Tremblay, M. A. 1957. The key informant technique: a nonethnographic application. Am. Anthropol. 59(4):688–701 (doi: https://doi.org/10.1525/aa.1957.59.4.02a00100).
USDOJ and FTC, 2010. Guidelines for horizontal mergers. U.S. Dep. Justice and Fed. Trade Comm., Wash., D.C., 37 p. (avail. at http://ftc.gov/os/2010/08/100819hmg.pdf) (accessed on 20 Nov., 2010).

Van der Voo, L. 2013. Sharecroppers of the sea. Investigate west. Seattle Weekly, 8 Jan. (avail. at http://archive.seattleweekly.com/news/942344-129/story.html. Accessed online 8 Mar. 2015).
van Putten, I., and C. Gardner. 2010. Lease quota fishing in a changing rock lobster industry. Mar. Pol. 34:859–867 (doi: https://doi.org/10.1016/j.marpol.2010.01.008).
Wang, S. 1995. The surf clam ITQ management: an evaluation. Mar. Resour. Econ. 10(1):93–98 (doi: https://doi.org/10.1086/mre.10.1.42629101).
Whitmarsh, D. J. 1998. The fisheries treadmill. Land Econ. 74(3):422–427 (doi: https://doi.org/10.2307/3147122).
Wilen, J. E. 2000. Renewable resource economists and policy: what differences have we made? J. Environ. Econ. Manage. 39(3):306–327 (doi: https://doi.org/10.1006/jeem.1999.1110).
Young, O. R., D. G. Webster, M. E. Cox, J. Raakjær, L. Ø. Blaxekjær, N. Einarsson, R. A. Virginia, J. Acheson, D. Bromley, E. Cardwell, C. Carothers, E. Eythórsson, R. B. Howarth, S. Jentoft, B. J. McCay, F. McCormack, G. Osherenko, E. Pinkerton, R. van Ginkel, J. A. Wilson, L. Rivers III, and R. S. Wilson. 2018. Moving beyond panaceas in fisheries governance. Proc. Natl. Acad. Sci. 115(37):9,065–9,073 (doi: https://doi.org/10.1073/pnas.1716545115).

Characterization of the U.S. Gulf of Mexico and South Atlantic Penaeidae and Rock Shrimp (Sicyoniidae) Fisheries through Mandatory Observer Coverage, from 2011 to 2016

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Introduction

The southeastern shrimp trawl fishery impacts commercial, recreational, and ecologically important fish stocks (Pellegrin, 1982; Alverson et al., 1994; Nichols et al.[1]; NMFS[2,3]). Declines in several finfish species brought about Federal mandates to identify the reasons for stock declines and management measures necessary for rebuilding affected stocks (Magnuson-Stevens Fishery Conservation and Management Act, Public Law 94-265, as amended by the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (P.L. 109-479)).

Since the early 1990's, substantial progress has been made in addressing the complex issues associated with finfish bycatch reduction in the southeastern shrimp fishery (NMFS[4]). Bycatch reduction devices (BRD's) developed by industry, scientists, and gear specialists continue to be evaluated through cooperative multi-year efforts among numerous organizations (Scott-Denton and Nance, 1996; Nance and Scott-Denton, 1997; Watson et al., 1999; Scott-Denton, 2007; Scott-Denton et al., 2012; Parsons and Foster, 2015; NMFS[2, 3, 4];Branstetter[5]; Nance et al.[6]; Foster and Scott-Denton[7]; Helies and Jamison[8]). A voluntary component of the observer program continues, to a lesser degree, to assess TED's and BRD's. BRD designs currently required for use in Federal waters of the Gulf of Mexi-

[1]Nichols, S., A. Shah, G. J. Pellegrin, Jr., and K. Mullin. 1987. Estimates of annual shrimp fleet bycatch for thirteen finfish species in the offshore waters of the Gulf of Mexico. Rep. to Gulf Mex. Fish. Manage. Counc. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Pascagoula, Miss., 28 p.

[2]NMFS. 1995. Report to Congress: cooperative research program addressing finfish bycatch in the Gulf of Mexico and South Atlantic shrimp fisheries. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Reg. Off., St. Petersburg, Fla., 68 p.

[3]NMFS. 1998. Report to Congress: southeastern United States shrimp trawl bycatch program. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Galveston Lab., Galveston, Tex., 155 p.

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doi: https://doi.org/10.7755/MFR.82.1-2.2

[4]NMFS. 2006. Report to Congress: Gulf of Mexico shrimp trawl bycatch reduction. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Miami, Fla., 126 p.

[5]Branstetter, S. 1997. Bycatch and its reduction in the Gulf of Mexico and south Atlantic shrimp fisheries. Gulf South Atl. Fish. Found., Inc., Suite 740, Lincoln Center, 5401 W. Kennedy Blvd. Tampa, Fla., 27 p.

[6]Nance, J., E. Scott-Denton, E. Martinez, J. Watson, A. Shah, and D. Foster. 1997. Bycatch in the southeast shrimp trawl fishery: A data summary report. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Miami, Fla., SFA Task N-10.03, 25 p.

[7]Foster, D. G., and E. Scott-Denton. 2004. Status of bycatch reduction device performance and research in north-central and western Gulf of Mexico. Southeast Data Assessment Rev., South Atl. Fish. Manage. Counc., Charleston, S.C., SEDAR 7-DW-38, 50 p. (avail. at http://www.sefsc.noaa.gov/sedar/)

[8] Helies, F., and J. Jamison. 2009. Reduction rates, species composition, and effort: assessing bycatch within the Gulf of Mexico shrimp trawl fishery. Gulf South Atl. Fish. Found., Inc., Suite 740, Lincoln Cent., 5401 W. Kennedy Blvd. Tampa, Fla., 182 p.

ABSTRACT—A mandatory Federal observer program was established in July 2007 to characterize the U.S. Gulf of Mexico penaeid shrimp fishery. The program grew in scope in June 2008 to include the South Atlantic Penaeidae and rock (Sicyoniidae) shrimp fisheries. In 2012, following an increase in sea turtle (Chelonioidea) strandings, observer coverage expanded to coastal waters of the northern Gulf of Mexico for skimmer trawl vessels and in 2016 for state-licensed otter trawl vessels. From January 2011 through December 2016, data were collected from 27,116 tows during 11,118 sea days of observations aboard 1,134 trips. For the mandatory component, data from 24,679 tows (10,734 sea days) were analyzed by area and target species. The majority of tows sampled (65%) were off the coasts of Louisiana and Texas. The highest concentrated effort occurred off South Texas, Louisiana, and southwestern Florida. Gear, including net characteristics, bycatch reduction devices (BRD's), and turtle excluder devices (TED's), were fairly consistent for the penaeid and rock shrimp otter trawl fisheries.

By species categories, finfish comprised the majority (≥ 58%) of the catch in the Gulf of Mexico and southern U.S. Atlantic penaeid shrimp fisheries, while in the rock shrimp fishery, finfish and rock shrimp rates were similar. Bycatch to shrimp ratios were comparable to a 2007– 10 shrimp assessment but lower than reported in previous studies for the Gulf of Mexico penaeid shrimp fishery. Declining shrimp effort since 2002 combined with higher shrimp catch per unit of effort (CPUE) and several management measures most likely contributed to the lower bycatch ratios seen in more than a decade. Density surface plots for several commercial and recreational species illustrated spatial differences in distribution and CPUE. Hot Spot Analyses depicted areas with significant clustering of high or low CPUE for shrimp and bycatch species. Distribution of protected species interactions is illustrated both spatially and temporally.

co and South Atlantic include composite panel, extended funnel, fisheye, Jones-Davis, and modified Jones-Davis (NOAA, 2008). The expanded mesh BRD is certified for use in the South Atlantic only. Currently, no TED or BRD requirements are mandated for the skimmer trawl fishery; however, limited tow times apply due to the potential for sea turtle interactions.

Penaeid shrimp species, brown shrimp, *Farfantepenaeus aztecus*; white shrimp, *Litopenaeus setiferus*; and pink shrimp, *Farfantepenaeus duorarum*, have historically comprised the majority of shrimp landed in southeastern U.S. waters. These three species accounted for 97.8 % of annual shrimp landed in the Gulf of Mexico in 2016 (NMFS, 2017). Landings were approximately 206.9 million lb (heads-on) valued at $354.1 million (NMFS, 2017). Penaeid shrimp landings in the South Atlantic were approximately 18.0 million lb (heads-on) valued at $38.6 million. Rock shrimp, *Sicyonia* spp., also primarily targeted in the South Atlantic, accounted for a smaller percentage of landings (1.1 million lb) valued at $1.6 million (NMFS, 2017).

The penaeid otter-trawl shrimp fishery operates year-round in the Gulf of Mexico, with the highest effort occurring May through December (Nance, 1993a). Brown shrimp are primarily caught in offshore waters off the coasts of Texas and Louisiana in depths between 20 and 40 fm, with white shrimp typically captured in waters of about 10 fm in the same areas. Pink shrimp occur in waters of about 35 fm, predominately off southwestern Florida in the winter months (NMFS, 1999). Rock shrimp are targeted in waters primarily off the east coast of Florida in depths between 10-40 fm (Anderson, 1956; Nance, 1993b). In the northern Gulf of Mexico, the skimmer trawl fishery typically captures brown shrimp from May through July and white shrimp from August through December (Pulver et al., 2014).

Currently, there are 1,343 Federally permitted penaeid vessels in the Gulf of Mexico, 481 in the South Atlantic, and 98 rock shrimp vessels recorded as valid (SERO[9]). Observer coverage of the entire southeastern shrimp fishery is approximately 2% based on industry effort (nominal days at sea).

While finfish are the primary bycatch, other species listed under the Endangered Species Act (ESA) of 1973 as amended (16 U.S.C. 1536 et seq.), or other regulatory mandates, have been documented in the southeastern shrimp fishery. These include the following sea turtle species: Kemp's ridley, *Lepidochelys kempii*; leatherback, *Dermochelys coriacea*; hawksbill, *Eretmochelys imbricata*; loggerhead, *Caretta caretta*; and green, *Chelonia mydas*. These sea turtles occur in the Gulf of Mexico and South Atlantic and may be affected by shrimping activities (Magnuson et al., 1990; Epperly et al., 2002; Price and Gearhart, 2011; Scott-Denton et al., 2014; Gray and Kennelly, 2018). All of these species are currently listed as threatened or endangered under the ESA.

While less common, other protected species encountered include smalltooth sawfish, *Pristis pectinata*, listed by National Marine Fisheries Service (NMFS) as endangered under the ESA in April 2003 (50 CFR 224). Atlantic sturgeon, *Acipenser oxyrinchus oxyrinchus*, and Gulf sturgeon, *Acipenser oxyrinchus desotoi*, were listed by NMFS as endangered species in February 2012 (NOAA, 2012). The brown pelican, *Pelecanus occidentalis*, was delisted in November 2009 under ESA, but remains protected under the Migratory Bird Treaty Act (16 U.S.C. §§ 703-712). Lastly, the Marine Mammal Protection Act (MMPA), enacted in 1972 (16 USC Chpt. 31), provides protection for marine mammals.

The continuing goal of the mandatory shrimp observer program is to provide quantitative biological, vessel, and gear-selectivity information for the southeastern shrimp fishery. The primary objectives are to 1) provide general fishery characterization and catch rates for shrimp and bycatch species by area and target species and 2) provide catch rates that managers can use to estimate protected species bycatch levels.

The specific objectives of this manuscript are to 1) provide trip, vessel, environmental, and gear characteristics by gear type, target species, and area; 2) quantify shrimp and bycatch including protected species, by gear type, target species, and area; and 3) estimate catch per unit of effort (CPUE) trends and spatial distribution for target and nontarget species.

Methods

Methods are similar to those as described for the 1992 through mid-2007 voluntary shrimp observer program (Scott-Denton, 2007; NMFS[3]; Foster and Scott-Denton[7]) and, for the most part, the same as the first years of the mandatory program (Scott-Denton et al., 2012). NMFS-approved observers were placed on randomly selected vessels in the Gulf of Mexico based on the previous full year of effort stratified by area, depth, and season. Shrimp landings data were used to allocate sampling effort for the South Atlantic selection proportionally. Triannual selection periods each year were as follows: January through April, May through August, and September through December. For the rock shrimp fishery, one selection occurred for July through November. Selection periods varied for the inshore and nearshore shrimp fisheries due to seasonal closures in state waters.

The authority to place observers falls under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA; 16 USC 1801), ESA, and MMPA. Pursuant to MSFCMA § 303(b)(8), fishery permit holders are required to carry an observer if selected for mandatory coverage. MSFCMA § 303(b)(8) mandates that vessel operators obtain a current Commercial Fishing Vessel Safety Examination decal prior to the selection period for mandatory observer coverage.

[9]SERO. 2016. Fishery permits. Southeast Reg. Off., Natl. Mar. Fish Serv., NOAA, St. Petersburg, Fla. (avail. at http://sero.nmfs.noaa.gov/sf/permits.htm).

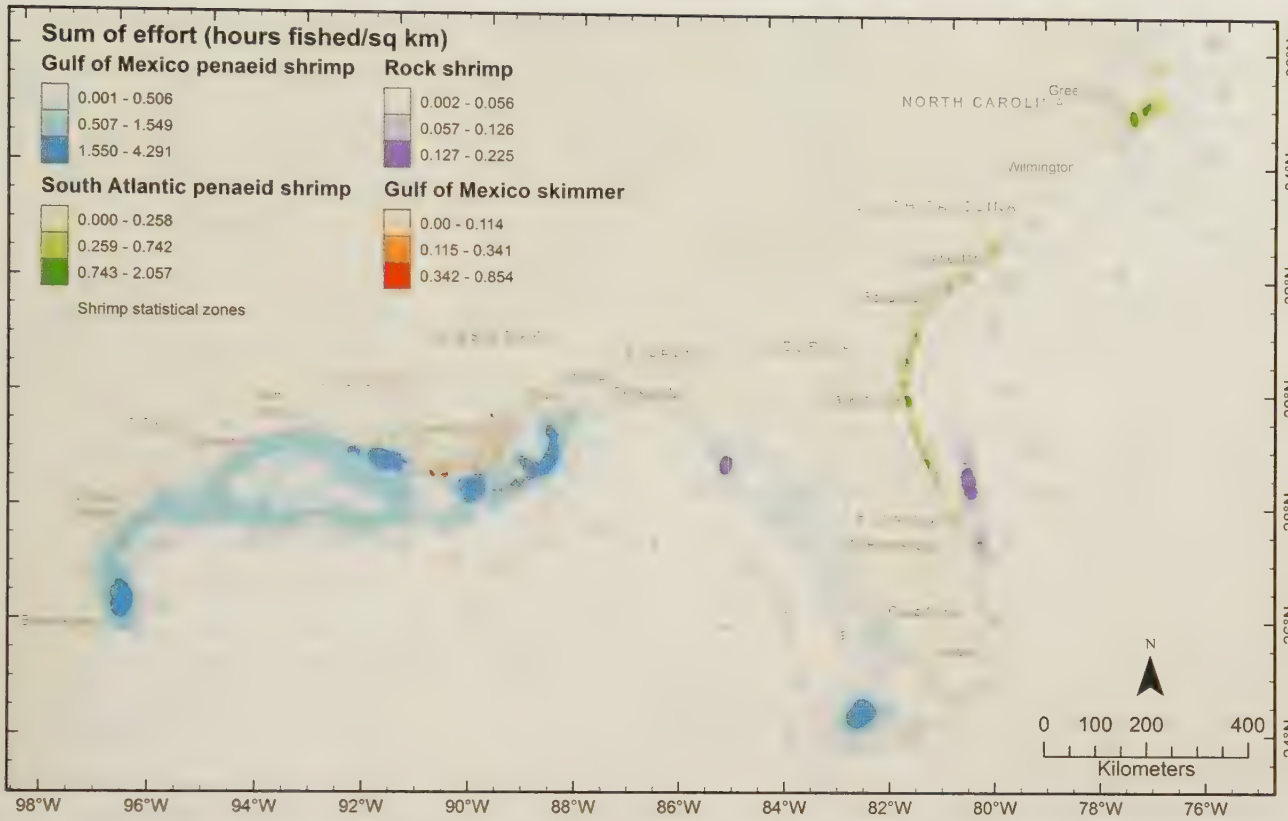

Figure 1.—Distribution of sampling effort (sum of tow times) based on observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

A minimum sea day requirement by permit type was established to prevent early trip termination due to having an observer on board. Gulf of Mexico Federal penaeid shrimp permit holders are required to carry an observer for a minimum of 18 days during a selection period, with 11 and 6 days for rock and South Atlantic penaeid shrimp, respectively. For the state-licensed skimmer trawl and otter-trawl fisheries, the minimum number of days to carry an observer is five and can occur through multiple trips.

Statistical zones (Patella, 1975) were used to delineate area designations in the Gulf of Mexico (Fig. 1). Where statistical areas 1–9 denote areas off the west coast of Florida, areas 10–12 represent Alabama/Mississippi, areas 13–17 depict Louisiana, and areas 18–21 delineate Texas. Depth strata seaward of the beach, or International Regulations for Preventing Collisions at Sea 1972 (COLREGS) line, were categorized as nearshore (≤ 10 fm) or offshore (> 10 fm). For the Atlantic, lat. 24°00' N – 30°42.5' N depict the east coast of Florida, > lat. 30°42.5' N – 32°00' N denote Georgia, > lat. 32°00' N – 33°51.6' N represent South Carolina, and > lat. 33°51.6' N designate North Carolina.

For each observed trip, vessel length, hull construction material, gross tonnage, engine horsepower, and crew size information were documented. Gear characteristics associated with BRD, TED, net type, and other attributes were recorded at the start of each trip and updated if changes were made during the trip. Bottom time, vessel speed, and operational aspects relative to each net were documented for each tow.

For the otter trawl fisheries, fishery-specific data were collected for each tow from the two outboard nets from vessels equipped with four nets, and one net for vessels equipped with two nets. Total catch and weights of shrimp and red snapper, *Lutjanus campechanus*, were recorded for each net sampled. A subsample (one basket per net; about 32 kg) was processed from each net for bycatch composition by sorting for species, family, or species groupings (now referred to as species). Sampling techniques were slightly modified to accommodate framed nets used in the skimmer trawl fishery (Pulver et al., 2012; Scott-Denton et al., 2014).

Species of commercial, recreational, and ecological importance were recorded. A detailed description of at-sea collection methods by gear type and area, species listings, and data requirements are presented in the NMFS Galveston Laboratory's observer manual "Characterization of the U.S. Gulf of Mexico and Southeastern Atlan-

tic Otter Trawl and Bottom Reef Fish Fisheries" (NMFS[10]).

All shark species (predominantly family Carcharhinidae) were grouped from 2007 through 2008. Beginning in January 2009, identification of some shark species was implemented.

Biological measurements (weight and length) were recorded in metric units. Vessel, gear, and depth measurements followed current standards for the fisheries (U.S. system equivalents) as related to relevant regulatory mandates.

Catch rates are presented collectively for all years and seasons by area and target species (Gulf of Mexico penaeid otter trawl; South Atlantic penaeid otter trawl; rock shrimp otter trawl; and penaeid skimmer trawl). A minimum of three vessels was required for seasonal and state-specific analyses due to confidentiality restrictions.

Protected species were documented and reported to the NMFS Southeast Regional Office (SERO) and/or the NMFS Southeast Fisheries Science Center (SEFSC), generally within 24 h of capture. Sighting or capture of sea turtles were recorded in accordance with SEFSC protocol (NMFS, 2008). Observer data pertaining to sea turtle interactions and other protected resources were sent to SEFSC for take level estimations.

Statistical Analyses

Species total weights, extrapolated from subsample weight using the total catch weight, were based on all sampled nets (sampling unit) per tow. To depict standard shrimp operations, data from all sampled nets, regardless of operational problems (e.g., torn webbing, hangs, clogging), were included. Total weight extrapolations were derived by multiplying the sample weight of the species of interest by the total weight of the sampled net, divided by the subsample weight for that net. For rare species and red snapper, all specimens were removed from the net. Thus, no extrapolation was required. Ratio estimation was used for analyses of species-specific catch rates (Snedecor and Cochran, 1967; Watson et al., 1999; Scott-Denton et al., 2012).

To standardize discard (bycatch) estimates, the coefficient of variation (CV) was used as a measure of precision for bycatch estimates (NMFS, 2004). The estimated standard error was divided by the estimate of the mean CPUE (kg per hour for selected species) to calculate the CV estimates.

As described in Scott-Denton et al. (2012), a density surface of CPUE for commercial and recreationally important species was created using Fishery Analyst[11,12] to graphically present temporal and spatial trends in fishery statistics (Riolo, 2006). The search radius was based on the average minimum tow length plus the standard deviation for each fishery (20 km for Gulf penaeid and rock shrimp; 10 km for South Atlantic penaeid; 5 km for skimmer trawl). A cell size of 1 km produced the finest resolution. To identify patterns in CPUE for selected species in each fishery, a local spatial statistic, the Getis-Ord Gi* (Gi*), was calculated using the Hot Spot Analysis tool in ArcGIS[13] to locate clusters of features with similarly high or low values and to identify if geographical areas of particularly high levels of bycatch occurred.

Results

Fishing Characteristics

From January 2011 through December 2016, a total of 1,134 trips were observed (Table 1). For the mandatory component, 24,679 tows targeting penaeid, rock, and/or royal red shrimp were sampled during 10,734 sea days of observations. Royal red shrimp were not included in the analyses due to confidentially rules. The highest concentration of effort was in the Gulf of Mexico in statistical areas 2, 11–15, and 21 (Fig. 1). By season, 47% of the tows occurred from May through August; 35% September through December; and 18% January through April (Table 2). The greatest percentage of tows (43%) occurred off Louisiana.

Trip and tow characteristics varied by area and target (Table 3). Trip length averaged 17.2 (± 11.8 s.d.) days in the Gulf, 2.8 (± 3.6 s.d.) days in the South Atlantic penaeid shrimp fishery, 8.8 (± 6.4 s.d.) days for the rock shrimp fishery, and 2.9 (± 1.9 s.d.) in the Gulf skimmer fishery. Average tow times were longer in the Gulf (5.3 h ± 2.1 s.d.) as compared with rock shrimp (3.0 ± 0.8 s.d), South Atlantic penaeid (2.9 h ± 1.2 s.d.) and skimmer trawl (1.0 h ± 0.4 s.d.) shrimp fisheries. Try net (a small net used to intermittently test for shrimp concentrations) tow times were also longer in the Gulf (1.0 h ± 0.5 s.d.) as compared with rock (0.8 h ± 0.3 s.d) and South Atlantic penaeid (0.6 h ± 0.2 s.d) shrimp fisheries. Skimmer trawlers do not utilize try nets. On average, rock shrimp vessels fished greater depths (28.9 fm) than Gulf (15.0 fm), South Atlantic penaeid (4.8 fm), and skimmer trawl (1.8 fm) fisheries. Average vessel trawl speed for all areas and fisheries combined was 2.6 kn.

Vessel characteristics (Table 4) were similar for the Gulf penaeid and rock shrimp fisheries because they often target both penaeid and rock shrimp, though in different areas and times of the year. Gulf penaeid vessels are typically larger ($\bar{X}$ > 75.5 ft), have freezer storage capacity, and are of steel construction. The South Atlantic penaeid fishery has smaller vessels ($\bar{X}$ = 64.9 ft), ice hold storage, and wood construction. Skimmer trawl vessels are smallest ($\bar{X}$ = 42.5 ft), have ice hold storage, and of fiberglass construction.

[10]NMFS. 2010. Characterization of the U.S. Gulf of Mexico and southeastern Atlantic otter trawl and bottom reef fish fisheries. Observer Training Manual. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Galveston Lab., Galveston, Tex. (avail. at https://www.fisheries.noaa.gov/resource/document/southeast-otter-trawl-and-reef-fish-fisheries-observer-materials.

[11]Fishery Analyst, Mappamondo GIS, Via Rubens 3, 43100 Parma(PR) - Italy (avail. at http://www.mappamondogis.it/fisheryanalyst.htm).

[12] Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[13]ArcGIS 10.5 Computer Software. 380 New York Street, Redlands, Calif. 92373 (avail. at http://www.esri.com/software/arcgis/index.html).

Table 1.—Trips, tows, and sea days by year and program, based on observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

		Mandatory					Voluntary			
Item	Year	Gulf penaeid	South Atlantic penaeid	Rock	Skimmer	Deepwater Royal red	Experimental skimmer	North Carolina blue crab	Electronic monitoring pink shrimp (sawfish)	Total
Trips by year and project	2011	76	59	2		1	45			183
	2012	80	46		58		34	1		219
	2013	82	54	4	35	2	37			214
	2014	94	16	1	18	1	48		1	179
	2015	97	24	2	23	1	6			153
	2016	118	45	2	15	2	4			186
	Total	547	244	11	149	7	174	1	1	1,134
Tows by year and project	2011	2,677	275	50		43	352			3,397
	2012	2,610	370		765		437	2		4,184
	2013	3,357	322	70	1,075	48	315			5,187
	2014	3,570	177	24	634	51	787		62	5,305
	2015	3,297	202	40	371	19	249			4,178
	2016	3,749	405	43	359	76	233			4,865
	Total	19,260	1,751	227	3,204	237	2,373	2	62	27,116
Sea days by year and project	2011	1,273	102	21		26	72			1,494
	2012	1,413	140		119		63	1		1,736
	2013	1,588	127	30	145	14	51			1,955
	2014	1,731	68	9	82	15	103		33	2,041
	2015	1,555	88	19	44	8	33			1,747
	2016	1,869	164	18	47	19	28			2,145
	Total	9,429	689	97	437	82	350	1	33	11,118

Sea days by year and region	Year	Mandatory	Voluntary	Total	Industry sea days	Industry % cover
Gulf of Mexico	2011	1,320	32	1,352	66,777	2.0
	2012	1,532	42	1,574	70,505	2.2
	2013	1,747	11	1,758	64,788	2.7
	2014	1,856	122	1,978	73,683	2.7
	2015	1,664	33	1,697	66,849	2.5
	2016	2,033	28	2,061	72,609	2.8
	Total	10,152	268	10,420	415,212	2.5
South Atlantic	2011	102	40	142	16,933	0.8
	2012	140	22	162	19,020	0.9
	2013	157	40	197	13,950	1.4
	2014	49	14	63	14,657	0.4
	2015	50		50	15,450	0.3
	2016	84		84	14,919	0.6
	Total	582	116	698	94,929	0.7

Typical gear configurations for the southeastern otter trawl fishery are depicted in Scott-Denton et al. (2012), with Gulf skimmer trawls described in Pulver et al. (2012). Net characteristics by area and target species varied (Table 5). In the otter trawl fisheries, headrope length for the main nets ranged in size with an average of 49.8 ft in the Gulf penaeid to 61.0 ft in the rock shrimp fishery. Try net headrope for all otter trawl fisheries was approximately 12 ft. Several trawl characteristics in the Gulf and South Atlantic fisheries were similar including trawl body and codend material (nylon), door type (wood), trawl extension (none), chaffing gear (mesh), and lazy line rigging (elephant ears).

BRD type and dimensions (Table 6) were examined. The dominant BRD type (fisheye), BRD position (top), and BRD location (behind elephant ears) were recorded most often for the otter-trawl fisheries. Similarly, the dominant TED (Table 7) attributes included TED type and design (hard/curved bar), and TED angle ($\bar{X} \geq 48.5$ degrees).

Catch Composition

Based on actual weight (i.e., nonextrapolated) data, 5.0 million kg of total catch was documented from 30,890 nets (towing for 153,039 h). For nets that had an effort value and an associated total catch and shrimp weight recorded, 4.8 million kg of total catch were documented from 29,853 nets (147,474 h). Penaeid and rock shrimp comprised 1.3 million kg (heads-on) or 27% of the total weight. Average shrimp CPUE was 8.9 kg/h. From 29,587 nets (146,271 h) that had effort, total catch, shrimp and red snapper counts recorded, 269,698 total red snapper were documented in the Gulf of Mexico, yielding an average of 1.8 fish/h.

Extrapolated Species Composition Bycatch Ratios

For the 25,370 nets that contained species characterization data (including nets without effort), 4.4 million kg of total catch was recorded for all years, areas, seasons, and depths. Based on weight extrapolations from species composition samples, bycatch to targeted shrimp (penaeid or rock)

Table 2.—Percentage of tows by season and state, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Area	Jan–April %	May–Aug %	Sept–Dec %	Total %
Texas				
Nearshore	2.8	1.7	1.3	5.7
Offshore	1.5	4.6	10.4	16.5
Subtotal	4.2	6.3	11.7	22.3
Louisiana				
Nearshore	1.9	17.6	8.4	27.9
Offshore	4.8	5.8	4.2	14.8
Subtotal	6.7	23.4	12.6	42.7
Alabama/Mississippi				
Nearshore	0.6	5.9	3.9	10.5
Offshore	1.2	3.6	1.9	6.7
Subtotal	1.8	9.5	5.9	17.2
Florida Gulf				
Nearshore	1.2	0.5	0.4	2.1
Offshore	3.4	2.7	1.7	7.8
Subtotal	4.6	3.2	2.2	10.0
Florida Atlantic				
Nearshore	0.6	1.4	0.5	2.4
Offshore	0.0	0.6	0.2	0.8
Subtotal	0.6	2.0	0.7	3.3
Georgia				
Nearshore	0.1	0.4	0.6	1.1
Subtotal	0.1	0.4	0.6	1.1
South Carolina				
Nearshore	0.0	0.8	0.7	1.4
Subtotal	0.0	0.8	0.7	1.4
North Carolina				
Nearshore	0.0	1.4	0.6	2.0
Subtotal	0.0	1.4	0.6	2.1
Grand total	18.0	47.1	35.0	100.0

Table 3.—Trip characteristics by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Item	Gulf mandatory penaeid	South Atlantic mandatory penaeid	Mandatory rock	Gulf mandatory skimmer
Trip length (days)	*n*=547	*n*=244	*n*=11	*n*=149
Mean	17.2	2.8	8.8	2.9
Range	1.0–61.0	1.0–26.0	1.0–20.0	0–10.0
s.d.	11.8	3.6	6.4	1.9
Main net tow time (h)	*n*=19,198	*n*=1,751	*n*=225	*n*=3,203
Mean	5.3	2.9	3.0	1.0
Range	<0.1–22.2	0.1–8.0	0.2–5.9	<0.1–4.0
s.d.	2.1	1.2	0.8	0.4
Total hs	102,443.1	5,111.0	681.4	3,152.8
Try net towtime (h)	*n*=31,441	*n*=4,342	*n*=284	
Mean	1.0	0.6	0.8	
Range	<0.1–5.6	<0.1–1.9	0.2–1.9	
s.d.	0.5	0.2	0.3	
Water depth (ftm)	*n*=18,977	*n*=1,736	*n*=227	*n*=3,126
Mean	15.0	4.8	28.9	1.8
Range	0.6–100.3	0.8–12.7	11.0–76.3	0.2–20.5
s.d.	11.9	2.5	13.4	1.8
Vessel speed (kt)	*n*=19,126	*n*=1,746	*n*=227	*n*=3,203
Mean	2.9	2.6	2.7	2.2
Range	0.5–4.2	1.4–22.9	2.2–3.1	0.0–5.3
s.d.	0.3	0.6	0.2	0.6

ratios by area and target species (Table 8) were 2.54 in the Gulf penaeid shrimp fishery, 3.50 for the South Atlantic penaeid, 1.68 in rock shrimp, and 1.19 in the Gulf skimmer trawl fishery. Finfish to shrimp ratios for these same fisheries were 2.08, 2.83 and 1.06, and 1.06, respectively.

A total of 166 species were identified (Table 9). For all areas and target species, four species comprised 70% of total catch: grouped finfish species (30.4%), Atlantic croaker, *Micropogonias undulatus* (16.0%), brown shrimp (12.3%), and white shrimp (11.4%).

Extrapolated Species Composition Gulf of Mexico Penaeid Shrimp

Weight extrapolations from species characterization data collected from 25,317 nets that had an associated effort value (134,819 h) were placed into major categories by area and target for all years, seasons, and depths (Fig. 2). In terms of percent composition and CPUE for the Gulf of Mexico penaeid shrimp fishery, finfishes dominated the catch at 59% (18.5 kg/h), followed by penaeid shrimp at 28% (8.9 kg/h), crustaceans at 6% (1.9 kg/h), invertebrates at 5% (1.6 kg/h), and debris at 2% (0.5 kg/h). Overall (total catch) CPUE was 31.5 kg/h.[14]

At the species level, the dominant species by area and target are depicted (Fig. 3–6; Table 9). In the Gulf of Mexico penaeid shrimp fishery, 148 species were identified (Table 9). As to percent composition and CPUE (Fig. 3), grouped finfish accounted for 32% (10.3 kg/h) of the total catch, followed by Atlantic croaker, at 16% (4.9 kg/h), brown shrimp at 13% (4.0 kg/h), white shrimp at 11% (3.6 kg/h), crustaceans at 6% (1.9 kg/h), seatrout, *Cynoscion* spp., at 5% (1.7 kg/h), invertebrates at 5% (1.6 kg/h), pink shrimp at 3% (1.1 kg/h), longspine porgy, *Stenotomus caprinus,* at 3% (1.0 kg/h), and debris at 2% (0.5 kg/h). All other species accounted for 4% of the catch.

CPUE and variance estimates for selected species collected from all sampled nets from January 2011 through December 2016 in the Gulf of Mexico penaeid shrimp fishery depict low (≤0.2) CV estimates (Table 10). The two exceptions were finetooth shark, *Carcharhinus isodon,* and Florida smoothhound shark, *Mustelus norrisi.*

Spatial CPUE density (kg/h) plots for several of these species and areas of high and low CPUE for target and bycatch species are depicted in Fig-

[14]Percentages may not equal 100% due to rounding.

ures 7–23 for all regions and targets. For the Gulf of Mexico region, brown and white shrimp were caught primarily in the western Gulf (statistical areas ≥11), with higher density CPUE for brown shrimp at a greater distance offshore as compared with white shrimp (Fig. 7, 8). Pink shrimp were distributed throughout the Gulf, with highest density CPUE occurring off the west coast of Florida (Fig. 9). Atlantic croaker, a dominant bycatch species, were caught throughout the Gulf region with highest spatial CPUE observed in statistical areas 11–18 (Fig. 10). Red snapper occurred primarily in the western Gulf and to a lesser extent off Florida in statistical areas 1–8 (Fig. 11).

For the Gulf of Mexico, cluster locations of statistically significant high CPUE for penaeid shrimp were most pronounced in relatively small concentrated cells of statistical areas 11–14, 2, and 6 (Fig. 12). For all discard (bycatch) species combined (Fig. 13), clusters of significantly high CPUE were most evident in statistical area 11 in the western Gulf, with relatively lower CPUE detected off south Texas (statistical area 21) and Florida (statistical area 2).

Table 4.—Vessel characteristics by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Item	Gulf mandatory penaeid	South Atlantic mandatory penaeid	Mandatory rock	Gulf mandatory skimmer
Vessel length (ft)	*n*=333	*n*=77	*n*=7	*n*=69
Mean	75.5	64.9	81.0	42.5
Range	34–98	24–88	68–88	26–61
s.d.	11.2	16.0	6.9	9.3
Year built	*n*=332	*n*=76	*n*=7	*n*=69
Mean	1990	1981	1994	1992
Range	1945–2015	1944–2001	1979–2001	1961–2013
s.d.	10.8	13.8	10.2	11.1
Gross tons	*n*=326	*n*=75	*n*=7	*n*=39
Mean	128.5	86.7	147.1	27.4
Range	7–219	1.5–175	114–175	3–49
s.d.	39.8	47.1	21.3	13.6
Horsepower	*n*=287	*n*=63	*n*=7	*n*=62
Mean	628	469.3	665.4	415.7
Range	76–1900	165–1080	360–800	165–1006
s.d.	265.9	211.3	158.6	196.9
Crew size	*n*=536	*n*=244	n=11	n=148
Mean	2	2	3	1
Range	0–4	0–4	2–3	0–3
s.d.	0.9	0.9	0.4	0.7
Cold storage				
Freezer	86.1%	27.3%	100%	3.6%
Ice	11.7%	71.4%		96.4%
Hull construction				
Steel	84.7%	36.4%	85.7%	17.6%
Fiberglass	10.8%	11.7%	14.3%	61.8%
Wood	1.5%	39.2%		6.6%
Fiberglass/Wood	2.5%	10.2%		11.0%

Extrapolated Species Composition South Atlantic Penaeid Shrimp

In the South Atlantic penaeid shrimp fishery, from 1,801 nets (5,521 h), fish species comprised 63% (32.8 kg/h) of the total catch (Fig. 2), followed by penaeid shrimp at 22% (11.6 kg/h), invertebrates at 11% (5.7 kg/h), crustaceans at 3% (1.5 kg/h), and debris at 1% (0.5 kg/h). Overall CPUE was 52.0 kg/h (rounding).

At the species level (Fig 4; Table 9), Atlantic croaker accounted for 25% (12.8 kg/h) of the total catch, followed by white shrimp at 13% (6.8 kg/h), grouped finfish at 12% (6.4 kg/h), spot (flat croaker), *Leiostomus xanthurus*, at 10% (5.4 kg/h), brown shrimp at 9% (4.4 kg/h), cannonball jellyfish, *Stomolophus meleagris,* at 5% (2.5 kg/h), seatrout, (*Cynoscion* spp.) and jellyfish (Family Carybdeidae) at 4% each (2.1 kg/h), star drum, *Stellifer lanceolatus*, at 4% (1.9 kg/h), and southern kingfish, *Menticirrhus americanus,* at 3% (1.5 kg/h). All other species (46) comprised 11% of the total weight.

CPUE and variance estimates for species selected from all sampled nets during the monitoring period in the South Atlantic penaeid shrimp fishery are depicted (Table 11). Relatively higher (≥0.2) CV estimates were observed in the South Atlantic as compared with the Gulf for several species including, but not limited to, sciaenids (Family Sciaenidae), seabasses (Family Serranidae), and sharks (predominantly Family Carcharhinidae).

Spatial CPUE density (kg/h) plots for several of these species are denoted in Figures 7–13. Brown and white shrimp were caught predominantly in statistical areas 28–32, with high CPUE observed in statistical area 35, in Pamlico Sound, North Carolina (Fig. 7, 8). Relatively low-density CPUE was observed for pink shrimp along the southeastern Atlantic coast (Fig. 9); the two exceptions occurred in statistical area 28, and in Pamlico Sound. Atlantic croaker occurred along the southeastern Atlantic coast, with highest CPUE density found in statistical area 35 (Fig. 10). Density surface of CPUE was not detectable for red snapper (Fig. 11). Cluster locations of statistically significant high CPUE for South Atlantic penaeid shrimp were most pronounced in statistical areas 30–32, and 35 (Fig. 12). For discarded species, clusters of significantly high CPUE were detected primarily in the statistical area 35 (Fig. 13).

Extrapolated Species Composition Gulf of Mexico and South Atlantic Rock Shrimp

In the rock shrimp fishery (342 nets; 1,044 h), finfish accounted for 40% (25.2 kg/h) of the total catch (Fig. 2), followed by rock shrimp at 37% (23.7 kg/h), crustaceans at 10% (6.6 kg/h), invertebrates at 8% (4.8 kg/h), penaeid shrimp at 3% (1.9 kg/h), and debris at 2% (1.2 kg/h). Total catch CPUE was 63.5 kg/h.

At the species level (Fig. 5; Table

Table 5.—Net characteristics by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Item	Gulf mandatory penaeid		South Atlantic mandatory penaeid		Mandatory rock		Mandatory skimmer	
Net type (%)	Unknown w/bib	21.2	Mongoose w/bib	57.0	2 seam	34.5	Skimmer trawl	97.1
	Unknown	11.9	4 seam	6.9	2 seam flat	34.5	Butterfly net	2.9
Main net headrope length (ft)		*n*=37,507		*n*=3,431		*n*=452		*n*=6,406
Mean		49.8		53.4		61.0		17.0
Range		16.0–96.7		25.0–89.4		39.1–68.2		11.0–29.6
s.d.		10.6		11.3		5.1		2.2
Main net footrope length (ft)		*n*=37,881		*n*=3,345		*n*=452		*n*=6,386
Mean		56.8		56.3		64.6		28.0
Range		16.0–90.0		24.1–87.5		48.0–72.9		16.0–38.0
s.d.		11.3		11.5		6.5		3.5
Try net headrope length (ft)		*n*=29,714		*n*=4,294		*n*=270		
Mean		12.1		11.9		12.0		
Range		5.0–21.2		6.2–16.5		6.2–16.1		
s.d.		1.4		1.6		1.2		
Try net footrope length (ft)		*n*=29,829		*n*=4,294		*n*=270		
Mean		13.4		12.7		13.4		
Range		5.0–24.0		9.4–16.5		12.0–16.0		
s.d.		2.0		1.4		1.4		
Trawl body (%)	Nylon	50.8	Nylon	38.8	Sapphire	69.5	Poly	65.5
	Sapphire	25.6	Spectra	38.4	Nylon	24.8	Nylon	17.5
Trawl body mesh size (in)		*n*=37,363		*n*=3,307		*n*=452		*n*=6,406
Mean		1.9		1.8		1.9		1.6
Range		1.3–3.0		1.3–2.3		1.5–2.0		1.3–2.4
s.d.		0.2		0.2		0.2		0.2
Cod end (%)	Nylon	63.4	Nylon	38.8	Nylon	65.0	Poly	58.4
	Sapphire	21.3	Poly	29.6	Sapphire	29.2	Nylon	36.5
Cod end mesh size (in)		*n*=36,856		*n*=3,285		*n*=452		*n*=6,264
Mean		1.6		1.6		1.7		1.4
Range		1.0–2.5		1.0–2.0		1.1–2.0		1.2–1.8
s.d.		0.2		0.2		0.3		0.1
Door type (%)	Wood	44.4	Wood	58.3	Aluminum	88.5	None	100.0
	Aluminum	32.8	Aluminum	34.1	Steel	10.6		
Door length (ft)		*n*=37,696		*n*=3,448		*n*=452		
Mean		9.5		8.6		10.6		
Range		3.5–13.3		3.3–12.0		8.9–12.0		
s.d.		2.0		1.8		0.8		
Door height (ft)		*n*=37,696		*n*=3,448		*n*=452		
Mean		3.6		3.4		3.7		
Range		2.5–6.0		2.0–5.0		3.3–4.3		
s.d.		0.3		0.4		0.2		
Dummy door length (ft)		*n*=30,688		*n*=2,656		*n*=452		
Mean		7.7		6.9		8.0		
Range		2.0–11.8		2.8–9.6		5.8–9.0		
s.d.		1.8		1.5		0.5		
Trawl extension type (%)	None	72.3	None	54.0	None	65.5	None	60.1
	Nylon	14.8	Nylon	26.4	Poly	18.1	Poly	24.0
Chaffing gear type (%)	Mesh	95.9	Mesh	86.0	Other	69.9	None	85.3
	None	3.4	None	7.2	Mesh	28.8	Mesh	14.7
Lazy line rigging (%)	Elephant ears	97.7	Elephant ears	90.9	Elephant ears	100.0	Choke	57.1
	Choke	2.0	Choke	8.1			Elephant ears	42.9
Tickler chain length (ft)		*n*=36,810		*n*=3,327		*n*=452		*n*=6,180
Mean		64.7		62.0		71.3		28.9
Range		27.0–100.7		25.0–100.7		50.5–84.1		15.0–46.9
s.d.		12.2		12.2		9.9		3.5

9), rock shrimp comprised 36% (22.7 kg/h) of the total catch, followed by grouped finfish at 22% (14.0 kg/h), invertebrates at 8% (4.8 kg/h), inshore lizardfish, *Synodus foetens,* at 7% (4.5 kg/h), longspine swimming crab, *Portunus spinicarpus*, at 6% (3.7 kg/h), dusky flounder, *Syacium papillosum*, at 6% (3.6 kg/h), crustaceans at 4% (2.5 kg/h), debris at 2% (1.2 kg/h), pink shrimp and rock seabass, *Centropristis philadelphica,* each at 2% (1.1 kg/h). All other species accounted for 7% of the total weight (rounding).

CV estimates for species selected from all sampled nets from July 2011 through December 2016 (Table 12) were higher (≥0.3), and in some instances equal to 1.0, for several species in the rock shrimp fishery.

Highest spatial CPUE density for rock shrimp detected in statistical areas 7 and 8 (Fig. 14). Highest CPUE density for grouped finfish was most evident in statistical areas 4, 29, and 30 (Fig. 15).

Cluster locations of statistically significant high CPUE for rock shrimp were most pronounced in statistical areas 7 and 8 (Fig. 16). The highest clus-

Table 6.—Bycatch reduction device (BRD) characteristics by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Item	Gulf mandatory penaeid		South Atlantic mandatory penaeid		Mandatory rock		Mandatory skimmer	
BRD type (% of nets)	Fish eye	73.6	Fish eye	84.1	Fish eye	78.8	Fish eye	52.3
	Composite panel	18.1	2 fisheye	11.2	Composite panel	21.2	None	47.7
BRD cod end length (meshes)		*n*=35,049		*n*=3,183		*n*=404		*n*=6,112
Mean		136.5		137.1		134.7		117.0
Range		79.0–268.0		50.0–287.0		100.0–167.0		60.0–271.0
s.d.		27.7		32.8		17.9		35.8
BRD circumference (meshes)		*n*=37,601		*n*=3,379		*n*=452		*n*=6,406
Mean		138.8		147.3		146.7		136.6
Range		86.0–210.0		111.0–200.0		109.0–150.0		87.0–200.0
s.d.		16.5		13.6		9.1		20.6
BRD distance to tie-off rings (ft)		*n*=35,999		*n*=3,358		*n*=452		*n*=3,353
Mean		10.8		10.2		11.1		6.5
Range		4.6–30.0		6.0–21.1		6.7–15.1		4.0–9.8
s.d.		3.6		2.3		2.0		1.1
BRD position (%)	Top	78.5	Top	94.2	Top	78.8	None	47.4
	None	10.7	None	4.8	None	21.2	Top	46.0
BRD escape shape (%)	Half moon	38.3	Diamond	65.7	Diamond	67.7	None	47.7
	Oval	36.6	Half moon	13.9	Rectangle	21.2	Oval	20.0
BRD fisheye escape height (in)		*n*=29,835		*n*=3,182		*n*=404		*n*=3,353
Mean		5.9		7.5		12.1		5.8
Range		4.0–26.0		4.0–28.0		5.0–27.0		3.5–9.0
s.d.		2.6		1.9		7.6		1.1
BRD fisheye escape width (in)		*n*=30,339		*n*=3,168		*n*=404		*n*=3,353
Mean		10.6		8.9		9.0		10.8
Range		5.0–32.0		5.0–28.0		8.0–10.0		7.0–18.0
s.d.		2.8		2.1		0.8		1.6
BRD location (%)	Behind	75.5	Behind	71.3	Behind	78.8	Behind	49.8
	Front	21.6	Front	25.1	Front	21.2	None	47.7

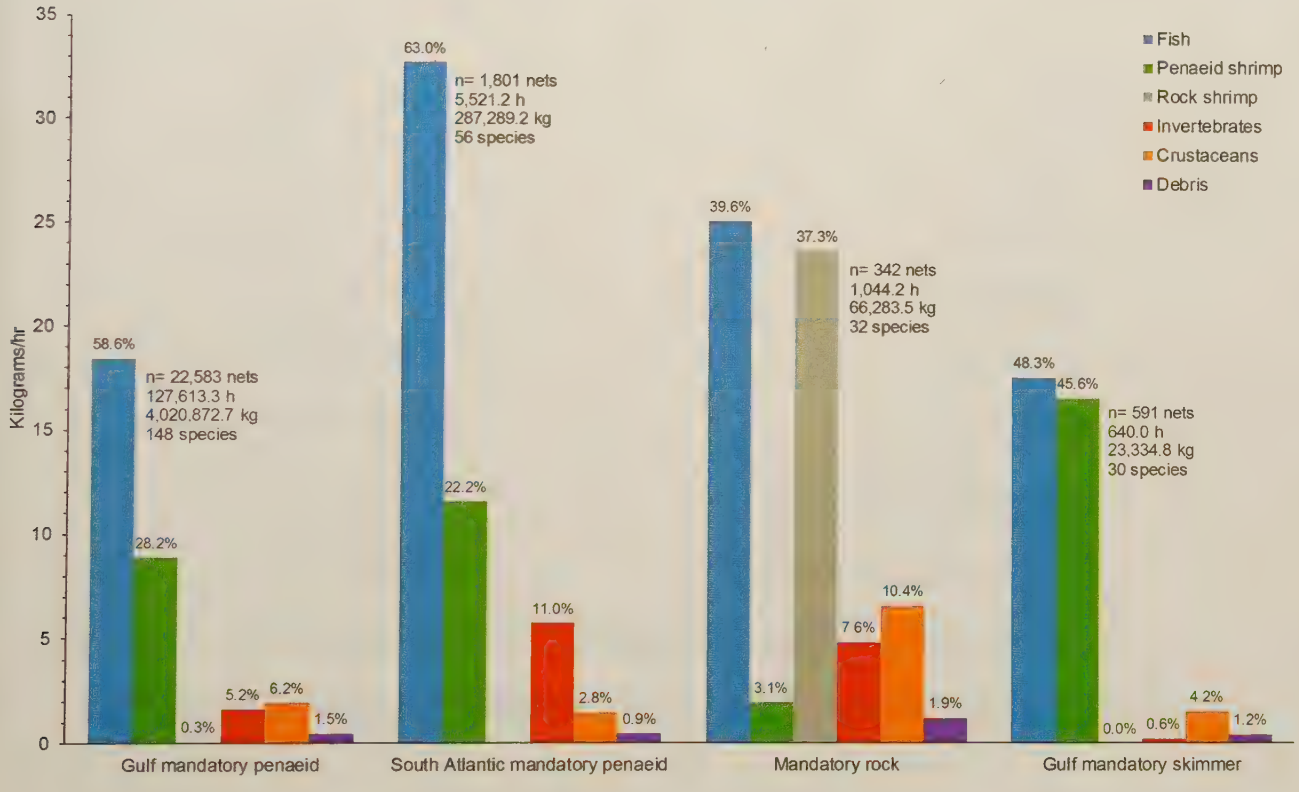

Figure 2.—Major species categories grouped by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Table 7.—Turtle excluder device (TED) characteristics, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Item	Gulf mandatory penaeid		South Atlantic mandatory penaeid		Mandatory rock		Mandatory skimmer	
TED type (%)	Hard	98.7	Hard	99.1	Hard	100.0	None	97.8
	None	1.2	Soft	0.9			Hard	2.2
TED design (%)	Curved bar	58.8	Curved bar	80.5	Curved bar	100.0	None	97.8
	Straight	39.5	Straight	18.6			Straight	2.2
TED opening (%)	Top	50.8	Bottom	80.3	Bottom	100.0	None	97.8
	Bottom	47.4	Top	19.7			Bottom	1.7
TED funnel (%)	No	87.8	No	94.6	Yes	65.0	None	71.1
	Yes	11.1	Yes	4.8	No	34.1	Unknown	23.3
TED flap (%)	Yes	98.1	Yes	97.0	Yes	100.0	None	67.2
	No	1.1	No	2.4			Unknown	23.3
TED material (%)	Aluminum	96.5	Aluminum	94.2	Aluminum	100.0	None	97.8
	Steel	1.3	Steel	3.4			Aluminum	1.7
TED angle (degrees)		*n*=36,721		*n*=3,370		*n*=452		*n*=100
Mean		48.5		51.4		51.9		47.7
Range		22.0–68.0		35.0–66.0		41.0–67.0		46.0–51.0
s.d.		5.4		4.6		5.2		1.8
TED length (in)		*n*=37,372		*n*=3,383		*n*=452		*n*=140
Mean		45.6		45.1		49.7		32.7
Range		30.0–60.0		34.0–64.0		48.0–53.0		32.0–35.0
s.d.		5.2		5.7		2.0		1.3
TED width (in)		*n*=37,469		*n*=3,383		*n*=452		*n*=140
Mean		38.7		36.9		38.8		32.7
Range		23.0–54.0		29.0–52.0		36.0–43.0		31.0–34.0
s.d.		3.5		4.2		2.2		1.3
TED PVC sponge (%)	Foam football	25.3	Foam football	52.6	Foam football	58.2	None	98.8
	Plastic round	24.1	Foam cylinder	13.1	Plastic cylinder	17.7	Foam cylinder	0.6
Number of TED floats		*n*=37,745		*n*=3,437		*n*=452		*n*=140
Mean		2.5		2.2		2.7		0.8
Range		0.0–6.0		0.0–4.0		2.0–3.0		0.0–2.0
s.d.		0.9		0.9		0.4		0.9
Try net TED type (%)	None	100	None	98.1	None	100.0		
			Soft	1.2				

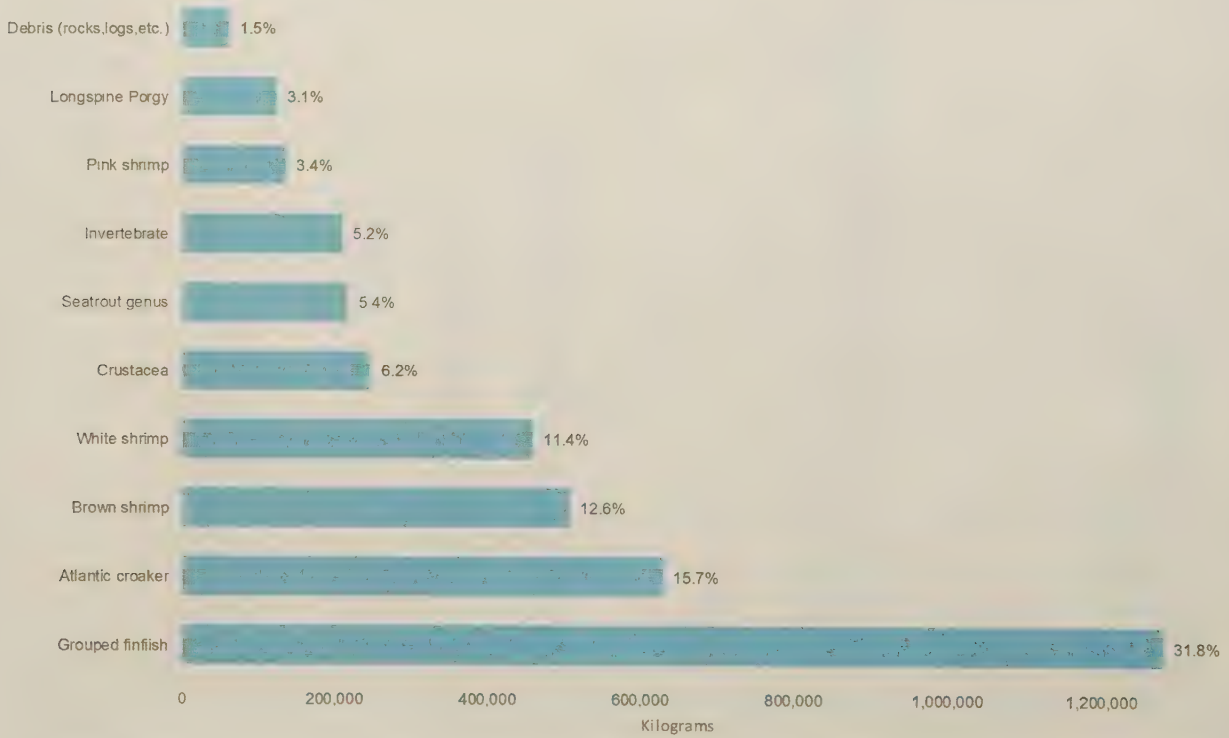

Figure 3.—Species-level characterization in the Gulf of Mexico penaeid shrimp fishery, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

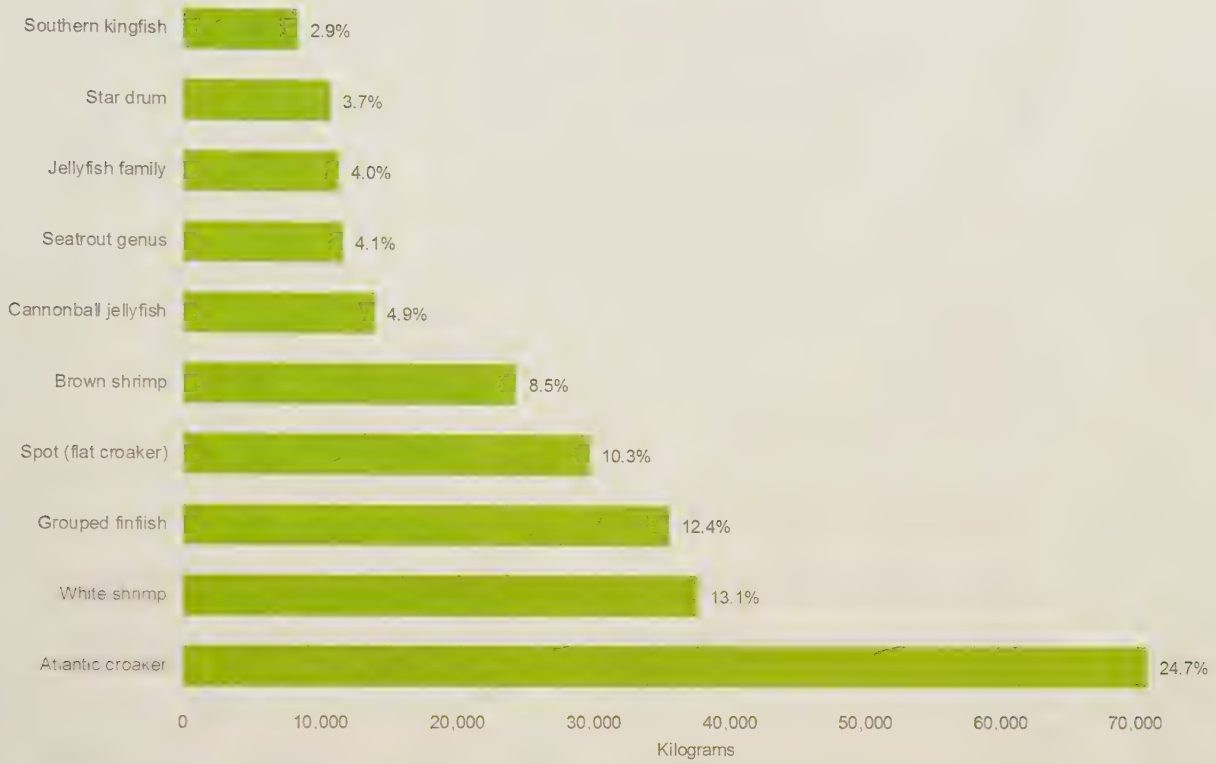

Figure 4.—Species-level characterization in the South Atlantic penaeid shrimp fishery, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

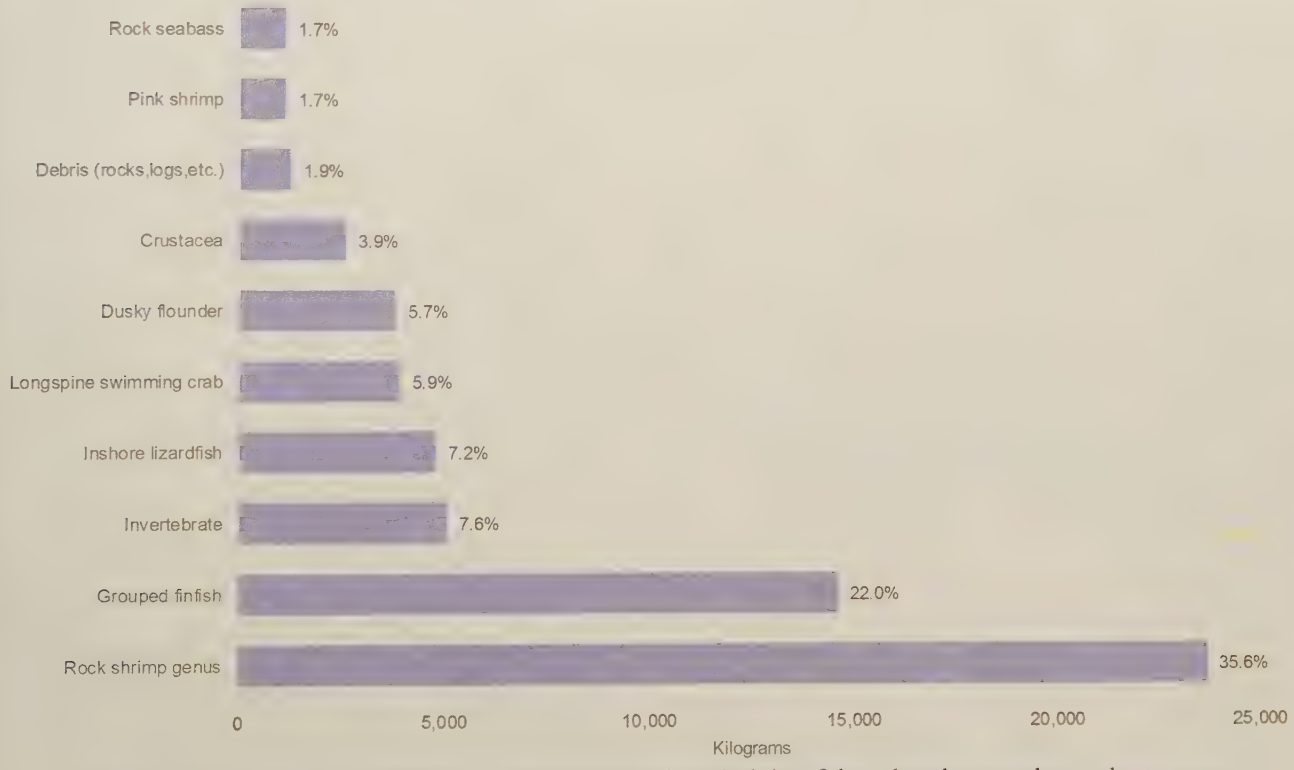

Figure 5.—Species-level characterization in the South Atlantic rock shrimp fishery, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

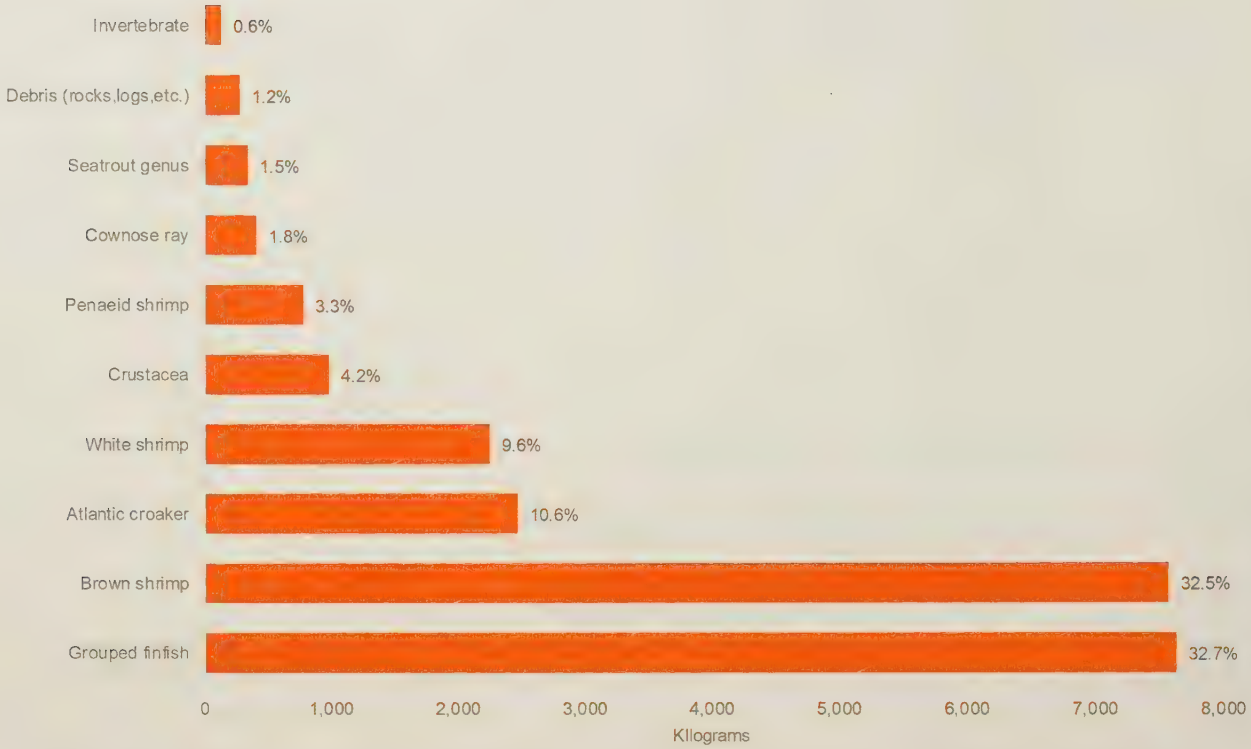

Figure 6.—Species-level characterization in the Gulf of Mexico skimmer shrimp fishery, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

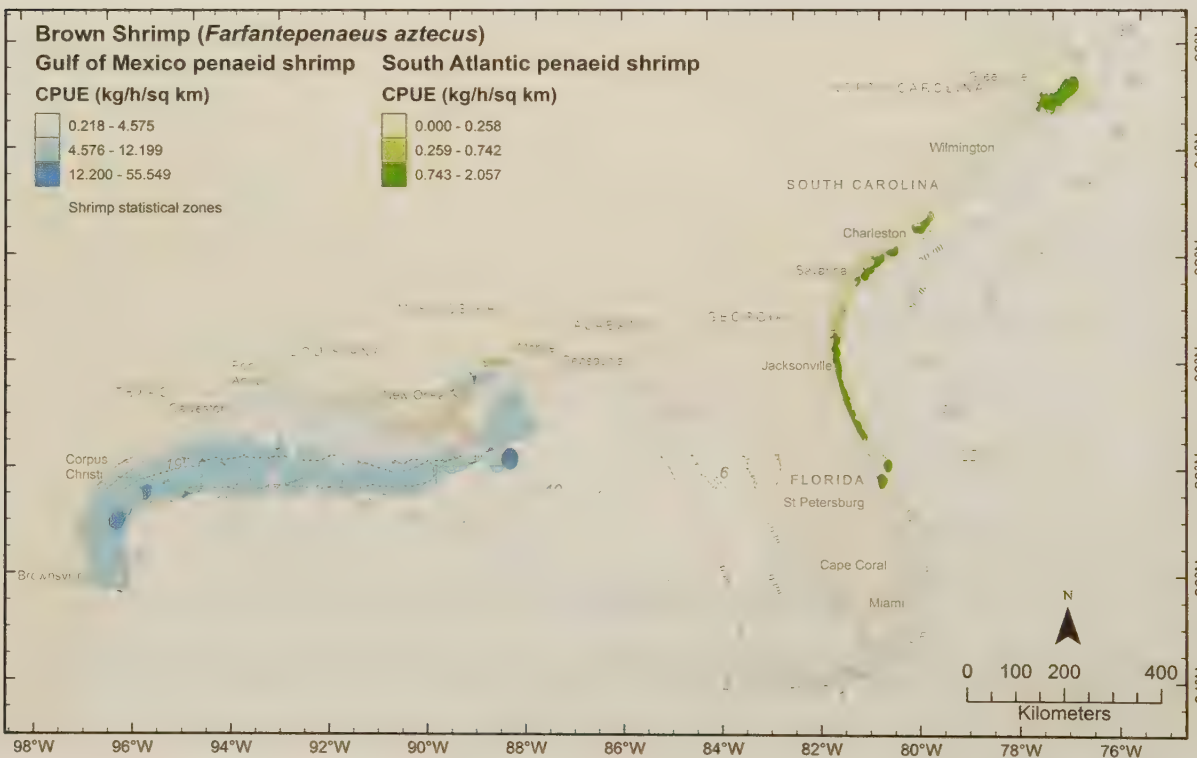

Figure 7.—CPUE density surface for brown shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Table 8.—Bycatch ratios by area and target species, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Project	Total (kg)	All bycatch: penaeid shrimp	Fish: penaeid shrimp	All bycatch: rock shrimp	Fish: rock shrimp
Gulf mandatory penaeid	4,020,872.7	2.54	2.08		
South Atlantic mandatory penaeid	287,289.2	3.50	2.83		
Mandatory rock	66,283.5			1.68	1.06
Gulf mandatory skimmer	23,334.8	1.19	1.06		

Table 9.—Species documented from bycatch characterization samples, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Common name	Scientific name	Gulf mandatory penaeid (kg)	Gulf mandatory penaeid (%)	South Atlantic mandatory penaeid (kg)	South Atlantic mandatory penaeid (%)	Mandatory rock (kg)	Mandatory rock (%)	Gulf mandatory skimmer (kg)	Gulf mandatory skimmer (%)	Total	Percent total
Fish (superclass)	*Pisces*	1,281,387.2	31.8	35,558.6	12.4	14,615.4	22.0	7,635.8	32.7	1,339,197.0	30.4
Atlantic croaker	*Micropogonias undulatus*	630,639.1	15.7	70,947.1	24.7	169.9	0.3	2,473.6	10.6	704,229.7	16.0
Brown shrimp	*Farfantepenaeus aztecus*	509,084.0	12.6	24,340.2	8.5	861.2	1.3	7,575.0	32.5	541,860.4	12.3
White shrimp	*Litopenaeus setiferus*	461,067.8	11.4	37,674.2	13.1	16.2	0.0	2,249.4	9.6	501,007.5	11.4
Arthropod subphylum	Crustacea	248,130.4	6.2	4,916.1	1.7	2,594.5	3.9	985.9	4.2	256,626.9	5.8
Seatrout (genus)	*Cynoscion* spp.	218,008.4	5.4	11,666.5	4.1	43.8	0.1	343.1	1.5	230,061.8	5.2
Invertebrate	Invertebrate	210,182.3	5.2	6,347.3	2.2	5,062.4	7.6	137.7	0.6	221,729.6	5.0
Pink shrimp	*Farfantepenaeus duorarum*	135,793.5	3.4	134.0	0.0	1,139.1	1.7			137,066.6	3.1
Longspine porgy	*Stenotomus caprinus*	124,005.8	3.1							124,005.8	2.8
Debris (rocks,logs,etc.)	Debris	61,360.1	1.5	2,562.1	0.9	1,268.1	1.9	279.7	1.2	65,470.0	1.5
Rock shrimp (genus)	*Sicyonia* spp.	11,305.6	0.3			23,704.6	35.6			35,010.3	0.8
Spot (flat croaker)	*Leiostomus xanthurus*	3,941.7	0.1	29,685.9	10.3	806.7	1.2			34,434.4	0.8
Discarded penaeid shrimp (brown, pink, white)	Penaeus discard	29,471.4	0.7	1,759.2	0.6	15.1	0.0	43.9	0.2	31,289.6	0.7
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	15,354.5	0.4	1,770.8	0.6	80.7	0.1	26.2	0.1	17,232.3	0.4
Red snapper	*Lutjanus campechanus*	13,990.9	0.3	1.2	0.0	0.3	0.0	0.0	0.0	13,992.4	0.3
Cannonball jellyfish	*Stomolophus meleagris*			13,979.9	4.9					13,979.9	0.3
Jellyfish family	Carybdeidae			11,361.6	4.0					11,361.6	0.3
Star drum	*Stellifer lanceolatus*	66.3	0.0	10,750.4	3.7					10,816.6	0.2
Spanish mackerel	*Scomberomorus maculatus*	9,593.9	0.2	471.5	0.2	1.5	0.0	69.4	0.3	10,136.3	0.2
Red drum	*Sciaenops ocellatus*	9,650.8	0.2	8.2	0.0			6.1	0.0	9,665.1	0.2
Southern kingfish	*Menticirrhus americanus*	1,077.4	0.0	8,401.7	2.9					9,479.1	0.2
Inshore lizardfish	*Synodus foetens*	3,720.6	0.1			4,796.2	7.2			8,516.8	0.2
Lane snapper	*Lutjanus synagris*	6,492.6	0.2	0.1	0.0	15.9	0.0	3.8	0.0	6,512.4	0.1
Southern flounder	*Paralichthys lethostigma*	5,487.4	0.1	660.4	0.2	47.2	0.1	48.2	0.2	6,243.2	0.1
Dusky flounder	*Syacium papillosum*	2,359.5	0.1			3,813.7	5.7			6,173.2	0.1
Longspine swimming crab	*Portunus spinicarpus*					3,914.7	5.9			3,914.7	0.1
Bonnethead shark	*Sphyrna tiburo*	2,950.7	0.1	834.3	0.3			1.6	0.0	3,786.6	0.1
Black drum	*Pogonias cromis*	3,737.2	0.1	3.3	0.0			32.5	0.1	3,773.0	0.1
Gulf menhaden	*Brevoortia patronus*	2,951.9	0.1							2,951.9	0.1
Blue crab	*Callinectes sapidus*	0.6	0.0	2,912.9	1.0					2,913.5	0.1
Weakfish	*Cynoscion regalis*			2,780.8	1.0					2,780.8	0.1
Pinfish	*Lagodon rhomboides*	2,725.5	0.1							2,725.5	0.1
Penaeid shrimp genus brown, pink, white)	*Penaeus* spp.	1,800.7	0.0					780.4	3.3	2,581.2	0.1
Blacktip shark	*Carcharhinus limbatus*	2,399.3	0.1	67.9	0.0			48.1	0.2	2,515.3	0.1
Atlantic bumper	*Chloroscombrus chrysurus*	2,488.8	0.1							2,488.8	0.1
Rock seabass	*Centropristis philadelphica*	545.7	0.0	590.8	0.2	1,124.8	1.7			2,261.3	0.1
Atlantic menhaden	*Brevoortia tyrannus*			2,154.0	0.7					2,154.0	0.0
Smooth dogfish shark	*Mustelus canis*	2,108.6	0.1	21.8	0.0					2,130.4	0.0
Atlantic cutlassfish	*Trichiurus lepturus*	2,079.5	0.1							2,079.5	0.0
Silver seatrout	*Cynoscion nothus*			2,040.2	0.7	2.4	0.0			2,042.7	0.0
Rock shrimp discards	Sicyonia discards	414.0	0.0			1,108.0	1.7			1,522.0	0.0
Gulf butterfish	*Peprilus burti*	1,436.1	0.0							1,436.1	0.0
King mackerel	*Scomberomorus cavalla*	1,246.2	0.0	132.8	0.0	2.5	0.0	0.3	0.0	1,381.8	0.0
Cownose ray	*Rhinoptera bonasus*	860.7	0.0					412.2	1.8	1,272.9	0.0
Northern kingfish	*Menticirrhus saxatilis*	1.2	0.0	929.4	0.3	81.5	0.1			1,012.1	0.0
Summer flounder	*Paralichthys dentatus*			856.0	0.3	47.6	0.1			903.6	0.0
Bank seabass	*Centropristis ocyurus*			2.9	0.0	785.6	1.2	0.1	0.0	788.6	0.0
Common crevalle jack	*Caranx hippos*	619.8	0.0					0.2	0.0	620.0	0.0
Sharks grouped	General sharks	552.9	0.0	19.8	0.0					572.7	0.0
Scalloped hammerhead shark	*Sphyrna lewini*	413.1	0.0	146.4	0.1					559.5	0.0
Hake (genus)	*Urophycis* spp.	514.7	0.0							514.7	0.0
Atlantic stingray	*Dasyatis sabina*	510.1	0.0							510.1	0.0
Sand perch	*Diplectrum formosum*	498.3	0.0							498.3	0.0
Sea bob shrimp	*Xiphopenaeus kroyeri*	238.6	0.0	258.2	0.1			1.0	0.0	497.9	0.0
Spinner shark	*Carcharhinus brevipinna*	486.5	0.0							486.5	0.0
Spotted seatrout	*Cynoscion nebulosus*	369.1	0.0	19.7	0.0			65.2	0.3	454.1	0.0
Iridescent swimming crab	*Portunus gibbesii*					422.1	0.6			422.1	0.0
Vermillion snapper	*Rhomboplites aurorubens*	399.4	0.0							399.4	0.0
Bluefish	*Pomatomus saltatrix*	1.2	0.0	370.4	0.1	4.3	0.0			375.8	0.0
Blacknose shark	*Carcharhinus acronotus*	300.2	0.0	7.5	0.0					307.7	0.0
Finetooth shark	*Carcharhinus isodon*	278.8	0.0	2.9	0.0					281.7	0.0

Table continued

Table 9.—*Continued.*

Common name	Scientific name	Gulf mandatory penaeid (kg)	Gulf mandatory penaeid (%)	South Atlantic mandatory penaeid (kg)	South Atlantic mandatory penaeid (%)	Mandatory rock (kg)	Mandatory rock (%)	Gulf mandatory skimmer (kg)	Gulf mandatory skimmer (%)	Total	Percent total
Angel shark	*Squatina dumeril*	279.1	0.0							279.1	0.0
Lefteye flounder family	*Bothidae*	272.7	0.0							272.7	0.0
Pigfish	*Orthopristis chrysoptera*	257.2	0.0							257.2	0.0
Slender mojarra	*Eucinostomus jonesi*	244.7	0.0							244.7	0.0
Cobia (ling)	*Rachycentron canadum*	228.0	0.0	1.0	0.0	11.0	0.0	0.2	0.0	240.1	0.0
Barbfish	*Scorpaena brasiliensis*	210.2	0.0							210.2	0.0
Spotfin mojarra	*Eucinostomus argenteus*	206.1	0.0							206.1	0.0
Rough scad	*Trachurus lathami*	170.4	0.0							170.4	0.0
Blackbelly rosefish	*Helicolenus dactylopterus*	157.6	0.0							157.6	0.0
Gafftopsail catfish	*Bagre marinus*	144.0	0.0							144.0	0.0
Sheepshead	*Archosargus probatocephalus*	79.2	0.0					44.5	0.2	123.7	0.0
Dogfish shark (genus)	*Mustelus* spp.	118.9	0.0	3.3	0.0					122.2	0.0
Mojarra (genus)	*Eucinostomus* spp.	121.4	0.0							121.4	0.0
Southern stingray	*Dasyatis americana*	116.7	0.0							116.7	0.0
Red goatfish	*Mullus auratus*	114.2	0.0							114.2	0.0
Smooth butterfly ray	*Gymnura micrura*	110.3	0.0							110.3	0.0
Brown rock shrimp	*Sicyonia brevirostris*	107.5	0.0							107.5	0.0
Tomtate	*Haemulon aurolineatum*	96.3	0.0							96.3	0.0
Tripletail	*Lobotes surinamensis*	70.1	0.0	17.3	0.0					87.4	0.0
Atlantic thread herring	*Opisthonema oglinum*	81.7	0.0							81.7	0.0
Bullnose ray	*Myliobatis freminvillei*	74.2	0.0							74.2	0.0
Silver jenny	*Eucinostomus gula*	72.4	0.0							72.4	0.0
Bull shark	*Carcharhinus leucas*	62.5	0.0					9.5	0.0	72.0	0.0
Atlantic moonfish	*Selene setapinnis*	57.1	0.0							57.1	0.0
Horseshoe crab	*Limulus polyphemus*			52.8	0.0					52.8	0.0
Silver perch	*Bairdiella chrysoura*	49.4	0.0							49.4	0.0
Roundel skate	*Raja texana*	49.0	0.0							49.0	0.0
Florida pompano	*Trachinotus carolinus*	10.6	0.0	35.9	0.0					46.5	0.0
Snapper (genus)	*Lutjanus* spp.	42.1	0.0							42.1	0.0
Alligator gar	*Atractosteus spatula*							39.8	0.2	39.8	0.0
Cubera snapper	*Lutjanus cyanopterus*	38.2	0.0							38.2	0.0
Southern hake	*Urophycis floridana*	37.1	0.0							37.1	0.0
Devil ray	*Mobula hypostoma*	36.9	0.0							36.9	0.0
Drum, kingfish (genus)	*Menticirrhus* spp.	26.1	0.0	7.6	0.0					33.7	0.0
Sandbar shark	*Carcharhinus plumbeus*	30.2	0.0							30.2	0.0
King snake eel	*Ophicthus rex*	27.2	0.0							27.2	0.0
Stingray (family)	Dasyiatidae	27.2	0.0							27.2	0.0
Black seabass	*Centropristis striata*			3.7	0.0	22.3	0.0			26.0	0.0
Dwarf sand perch	*Diplectrum bivittatum*	25.7	0.0							25.7	0.0
Leopard searobin	*Prionotus scitulus*	23.4	0.0							23.4	0.0
Red lionfish	*Pterois volitans*	23.4	0.0							23.4	0.0
Lefteye flounder (genus)	*Paralichthys* spp.	22.8	0.0	0.5	0.0					23.3	0.0
Longnose gar	*Lepisososteus osseus*	22.0	0.0							22.0	0.0
Hardhead catfish	*Arius felis*	21.8	0.0							21.8	0.0
Paddlefish	*Polyodon spathula*	0.3	0.0					21.2	0.1	21.5	0.0
Atlantic guitarfish	*Rhinobatos lentiginosus*	21.3	0.0							21.3	0.0
Blue catfish	*Ictalurus furcatus*	20.6	0.0							20.6	0.0
Warsaw grouper	*Epinephelus nigritus*	19.9	0.0							19.9	0.0
Gag	*Mycteroperca microlepis*	19.6	0.0							19.6	0.0
Wenchman	*Pristipomoides aquilonaris*	19.3	0.0							19.3	0.0
Tarpon	*Megalops atlanticus*	18.8	0.0							18.8	0.0
Gulf flounder	*Paralichthys albigutta*	16.3	0.0							16.3	0.0
Dusky shark	*Carcharhinus obscurus*	15.6	0.0							15.6	0.0
Tiger shrimp	*Penaeus monodon*	6.2	0.0	5.8	0.0					11.9	0.0
Great hammerhead shark	*Sphyrna mokarran*	11.3	0.0							11.3	0.0
Skate and ray (order)	Rajiformes	11.0	0.0							11.0	0.0
Lesser electric ray	*Narcine brasiliensis*	10.0	0.0							10.0	0.0
Searobin family	Triglidae	9.5	0.0							9.5	0.0
Mackerel (genus)	*Scomberomorus* spp.	8.5	0.0							8.5	0.0
Banded croaker	*Larimus fasciatus*	8.4	0.0							8.4	0.0
Snake eel (family)	Ophichthidae	7.8	0.0							7.8	0.0
Clearnose skate	*Raja eglanteria*	7.8	0.0							7.8	0.0
Twospot flounder	*Bothus robinsi*	7.6	0.0							7.6	0.0
Flounder (genus)	*Cyclopsetta* spp.	7.5	0.0							7.5	0.0
Yellowedge grouper	*Epinephelus flavolimbatus*	6.9	0.0							6.9	0.0
Ray (genus)	*Gymnura* spp.	6.8	0.0							6.8	0.0
Orange filefish	*Aluterus schoepfi*	6.7	0.0							6.7	0.0
Spiny dogfish	*Squalus acanthias*			6.4	0.0					6.4	0.0
Snowy grouper	*Epinephelus niveatus*	6.2	0.0							6.2	0.0
Florida smoothhound shark	*Mustelus norrisi*	6.2	0.0							6.2	0.0
Whitebone porgy	*Calamus leucosteus*	6.0	0.0							6.0	0.0
Striped burrfish	*Chilomycterus schoepfi*	5.5	0.0							5.5	0.0
Gray snapper	*Lutjanus griseus*	4.7	0.0	0.0	0.0					4.8	0.0
Broad flounder	*Paralichthys squamilentus*	4.0	0.0							4.0	0.0
Polkadot batfish	*Ogcocephalus radiatus*	3.9	0.0							3.9	0.0
Gulf bar-eyed tilefish	*Caulolatilus intermedius*	3.8	0.0							3.8	0.0

Table continued

Table 9.—*Continued.*

Common name	Scientific name	Gulf mandatory penaeid (kg)	Gulf mandatory penaeid (%)	South Atlantic mandatory penaeid (kg)	South Atlantic mandatory penaeid (%)	Mandatory rock (kg)	Mandatory rock (%)	Gulf mandatory skimmer (kg)	Gulf mandatory skimmer (%)	Total	Percent total
Jolthead porgy	*Calamus bajonado*	3.1	0.0							3.1	0.0
Swimming crab (genus)	*Callinectes* spp.			3.0	0.0					3.0	0.0
Spotted eagle ray	*Aetobatis narinari*	2.8	0.0							2.8	0.0
Sturgeon (genus)	*Acipenser* spp.			2.3	0.0					2.3	0.0
Atlantic torpedo	*Torpedo nobiliana*	2.1	0.0							2.1	0.0
Lionfish (genus)	*Pterois* spp.	1.8	0.0							1.8	0.0
Lizardfish family	*Synodontidae*	1.7	0.0							1.7	0.0
Streamer searobin	*Bellator egretta*	1.7	0.0							1.7	0.0
Scrawled cowfish	*Lactophrys quadricornis*	1.7	0.0							1.7	0.0
Spotted batfish	*Ogcocephalus pantostictus*	1.5	0.0							1.5	0.0
Honeycomb moray	*Gymnothorax saxicola*	1.4	0.0							1.4	0.0
Blue runner	*Caranx crysos*	1.3	0.0							1.3	0.0
Furcate spider crab	*Stenocionops furcatus*	1.1	0.0							1.1	0.0
Greater Amberjack	*Seriola dumerili*	1.0	0.0							1.0	0.0
Remora	*Remora remora*	1.0	0.0							1.0	0.0
Atlantic midshipman	*Porichthys plectrodon*	0.8	0.0							0.8	0.0
Blackedge moray	*Gymnothorax nigromarginatus*	0.8	0.0							0.8	0.0
Giant hermit crab	*Petrochirus diogenes*	0.7	0.0							0.7	0.0
Bonefish	*Albula vulpes*	0.7	0.0							0.7	0.0
Knobbed porgy	*Calamus nodosus*	0.6	0.0							0.6	0.0
Slipper lobster (genus)	*Scyllarides* spp.	0.6	0.0							0.6	0.0
Lined seahorse	*Hippocampus erectus*	0.3	0.0							0.3	0.0
Yellowtail snapper	*Ocyurus chrysurus*					0.3	0.0			0.3	0.0
Scup	*Stenotomus chrysops*			0.3	0.0					0.3	0.0
Scamp	*Mycteroperca phenax*	0.2	0.0							0.2	0.0
Mutton snapper	*Lutjanus analis*	0.1	0.0							0.1	0.0
Herring (genus)	*Alosa* spp.			0.1	0.0					0.1	0.0
Red grouper	*Epinephelus morio*	0.1	0.0							0.1	0.0
Gray triggerfish,	*Balistes capriscus*	0.0	0.0							0.0	0.0
Total		4,029,401.5	100.0	287,289.1	100.0	66,579.5	100.0	23,334.8	100.0	4,406,604.9	100.0

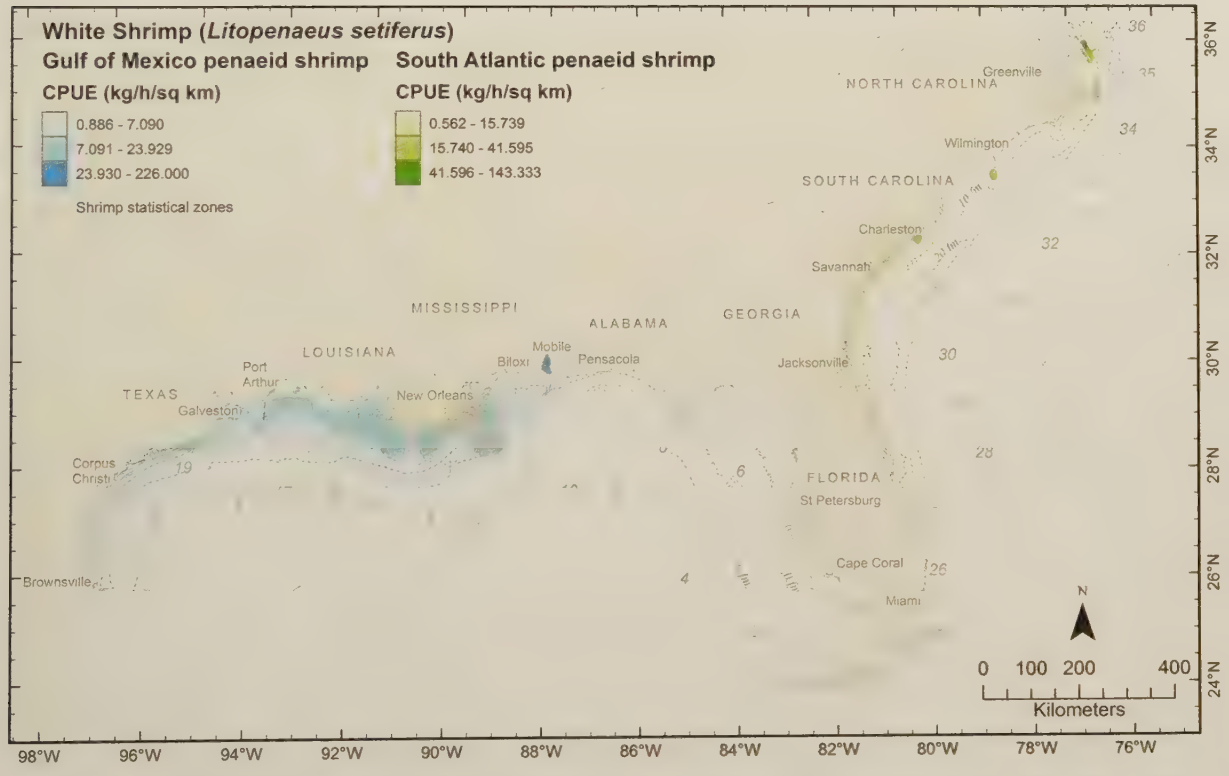

Figure 8.—CPUE density surface for white shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

ters of significantly high CPUE for discarded species were also in these areas and in statistical areas 29 and 30 (Fig. 17).

Extrapolated Species Composition Gulf of Mexico Skimmer Trawl Fishery

In the Gulf of Mexico skimmer trawl fishery, from 591 nets (640 h), fish species comprised 48% (17.6 kg/h) of the total catch (Fig. 2), followed by penaeid shrimp at 46% (16.6 kg/h), crustaceans at 4% (1.5 kg/h), debris at 1% (0.4 kg/h), and invertebrates at 1% (0.2 kg/h). Overall CPUE was 36.5 kg/h.

At the species level (Fig. 6; Table 9), grouped finfish accounted for 33% (11.9 kg/h) of the total catch, followed by brown shrimp at 33% (11.8 kg/h), Atlantic croaker at 11% (3.9 kg/h), white shrimp at 10% (3.5 kg/h), crustaceans at 4% (1.5 kg/h), grouped peneaid shrimp at 3% (1.2 kg/h), cownose ray, *Rhinoptera bonasus,* at 2% (0.6 kg/h), seatrout at 2% (0.5 kg/h),

Table 10.—Selected Gulf of Mexico fish species recorded from all penaeid shrimp nets from bycatch characterization samples, based on mandatory observer coverage from January 2011 through December 2016.

Scientific name	Common name	Extrapolated weight (kg)	Kg/h	CV
Negaprion brevirostris	Lemon shark	0.0	0.0	0.0
Pisces	Fish (superclass)	1,309,967.6	10.3	<0.1
Crustacean	Crustacean	248,077.4	1.9	<0.1
Farfantepenaeus aztecus	Brown shrimp	506,373.2	4.0	<0.1
Litopenaeus setiferus	White shrimp	461,007.8	3.6	<0.1
Micropogonias undulatus	Atlantic croaker	628,606.7	4.9	<0.1
Cynoscion spp.	Seatrout (genus)	217,714.9	1.7	<0.1
Invertebrate	Invertebrate	209,992.9	1.6	<0.1
Stenotomus caprinus	Longspine porgy	123,673.2	1.0	<0.1
Debris	Debris (rocks, logs, etc.)	61,337.3	0.5	<0.1
Farfantepenaeus duorarum	Pink shrimp	135,794.3	1.1	<0.1
Lutjanus campechanus	Red snapper	13,891.9	0.1	<0.1
Penaeus discard	Penaeid shrimp discard (brown,white, pink)	29,471.4	0.2	<0.1
Paralichthys lethostigma	Southern flounder	5,484.3	0.0	<0.1
Scomberomorus maculatus	Spanish mackerel	9,587.8	0.1	<0.1
Rhizoprionodon terraenovae	Atlantic sharpnose shark	15,348.4	0.1	<0.1
Lutjanus synagris	Lane snapper	6,492.6	0.1	<0.1
Sphyrna tiburo	Bonnethead shark	2,945.0	0.0	0.1
Sciaenops ocellatus	Red drum	9,650.8	0.1	0.1
Sicyonia spp.	Rock (genus) shrimp	11,305.7	0.1	0.1
Scomberomorus cavalla	King mackerel	1,244.2	0.0	0.1
Mustelus canis	Smooth dogfish shark	2,108.6	0.0	0.1
Pogonias cromis	Black drum	3,736.6	0.0	0.1
Carcharhinus limbatus	Blacktip shark	2,399.3	0.0	0.1
Sicyonia discards	Rock (discards) shrimp	414.0	0.0	0.1
Rhomboplites aurorubens	Vermilion (B-liner) Snapper	399.4	0.0	0.1
Cynoscion nebulosus	Spotted seatrout	369.1	0.0	0.1
Rachycentron canadum	Ling cobia	228.0	0.0	0.2
Carcharhinus acronotus	Blacknose shark	300.2	0.0	0.2
General sharks	Sharks grouped	229.0	0.0	0.2
Penaeid shrimp (brown,white, pink)	Penaeid shrimp (brown,white, pink)	1,800.7	0.0	0.2
Lutjanus spp.	Snapper (genus)	42.1	0.0	0.2
Sicyonia brevirostris	Brown rock shrimp	106.9	0.0	0.2
Carcharhinus brevipinna	Spinner shark	486.5	0.0	0.2
Carcharhinus isodon	Finetooth shark	278.8	0.0	0.3
Mustelus norrisi	Florida smoothhound shark	6.2	0.0	0.6

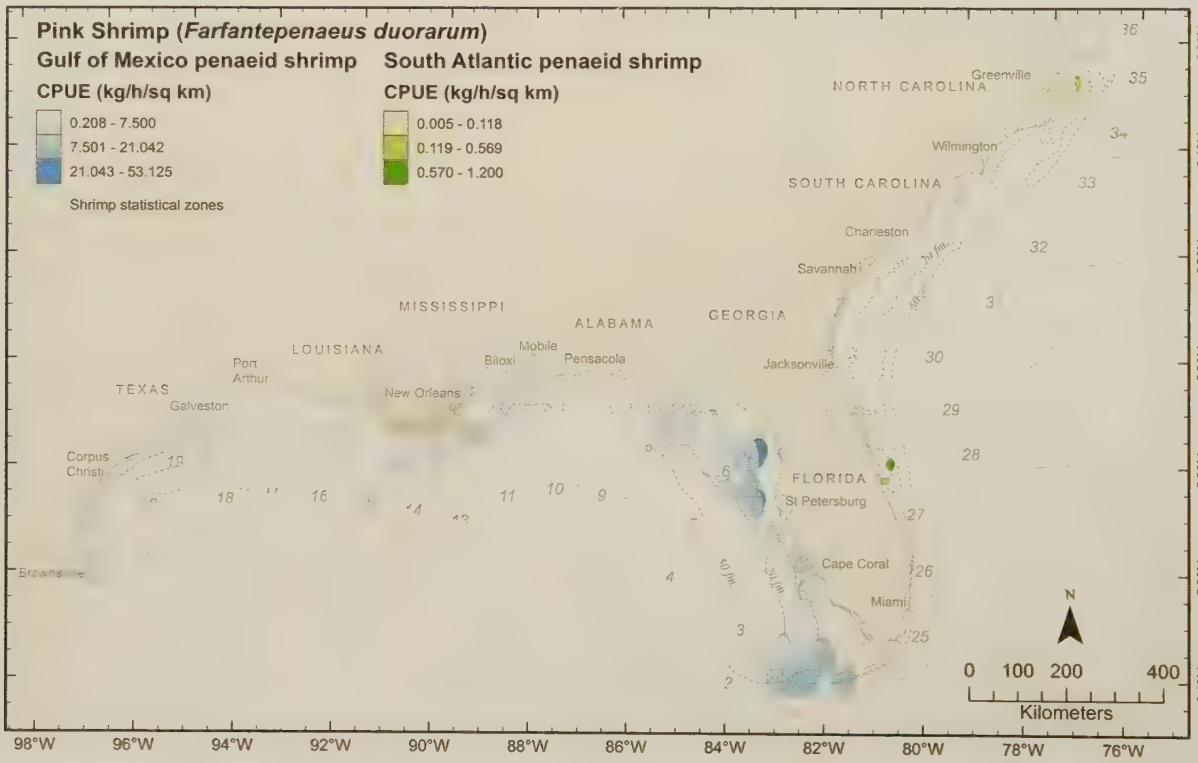

Figure 9.—CPUE density surface for pink shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

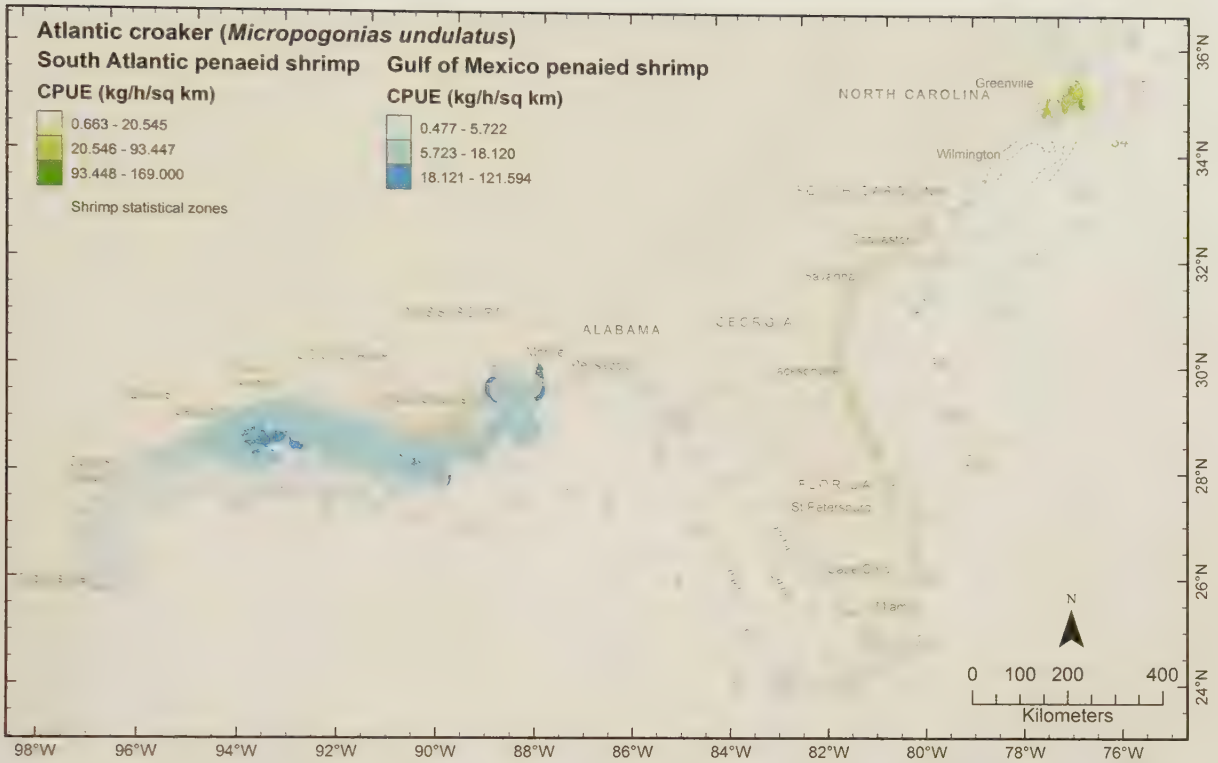

Figure 10.—CPUE density surface for Atlantic croaker by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

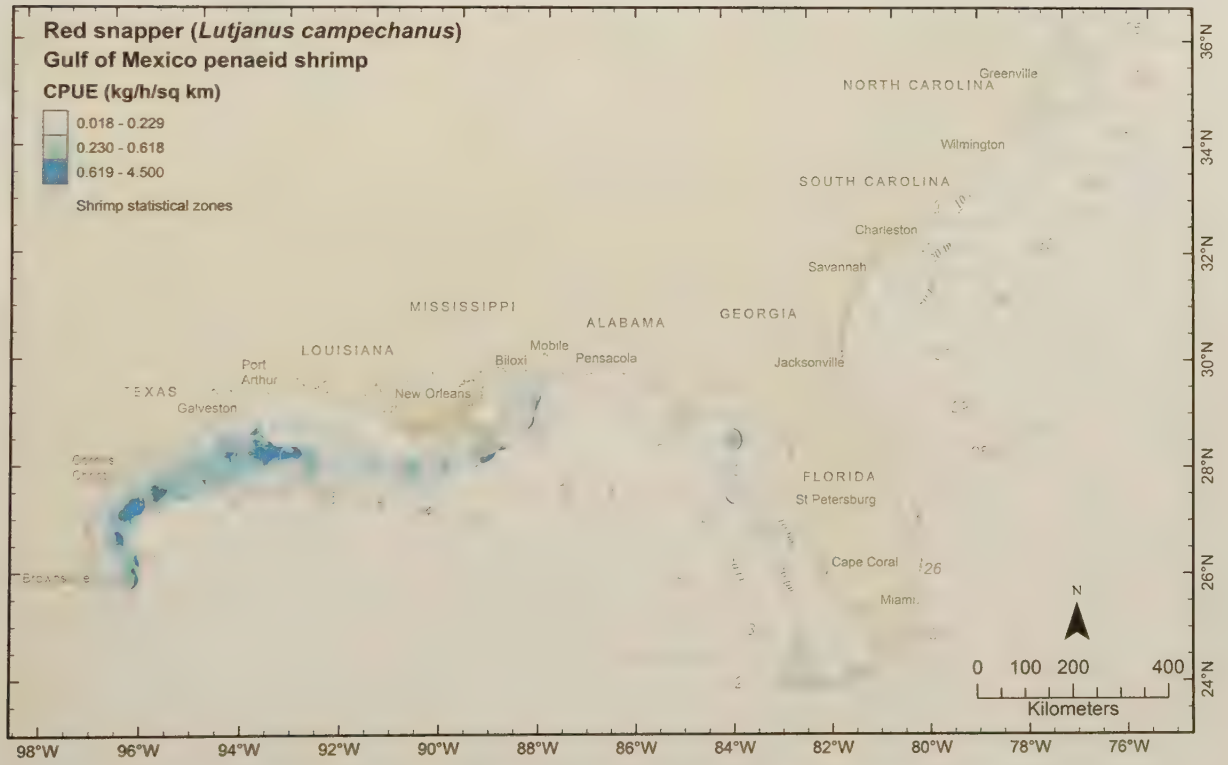

Figure 11.—CPUE density surface for red snapper by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

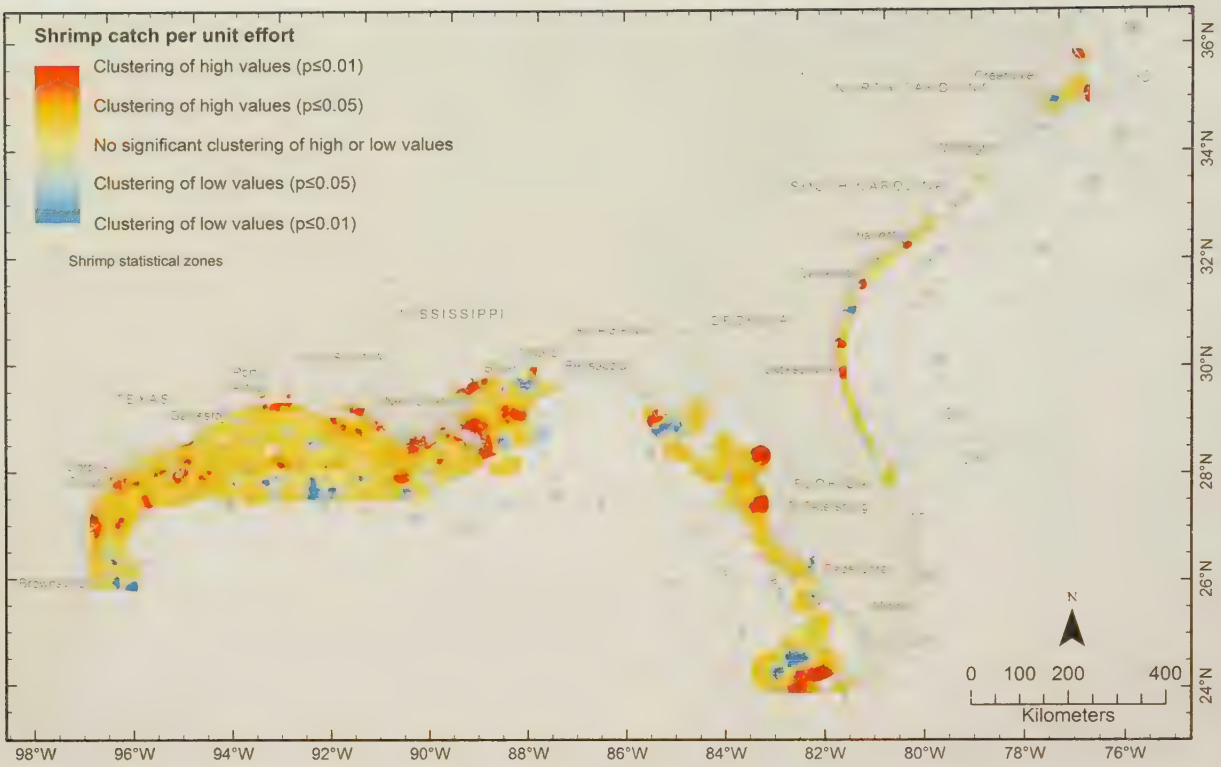

Figure 12.—Hot Spot Analysis for shrimp (penaeid or rock) by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

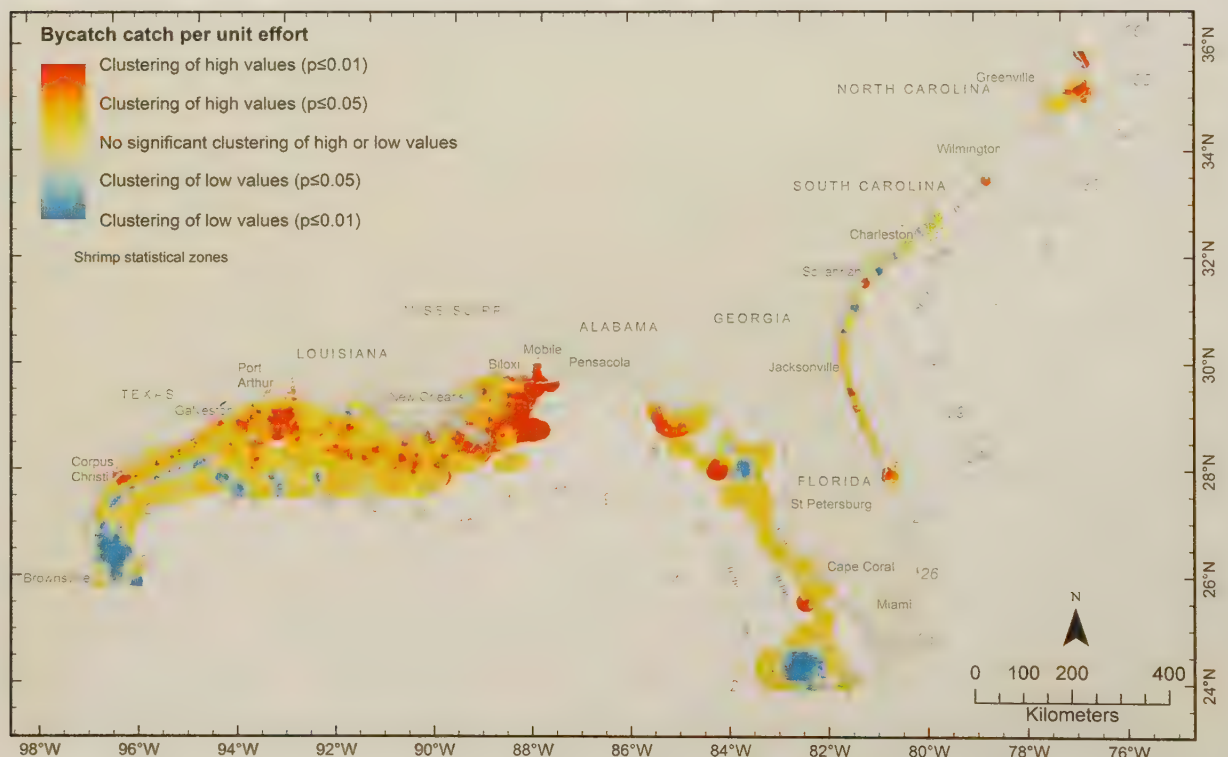

Figure 13.—Hot Spot Analysis for discard (bycatch) species by area and target, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

Table 11.—Selected South Atlantic fish species recorded from all penaeid shrimp nets from bycatch characterization samples, based on mandatory observer coverage from January 2011 through December 2016.

Scientific name	Common name	Extrapolated weight (kg)	Kg/h	CV
Carcharhinus brevipinna	Spinner shark	0.0	0.0	0.0
Carcharhinus falciformis	Silky shark	0.0	0.0	0.0
Mycteroperca microlepis	Gag	0.0	0.0	0.0
Penaeid shrimp (brown,white, pink)	Penaeid shrimp (brown,white, pink)	0.0	0.0	0.0
Litopenaeus setiferus	White shrimp	37,674.2	6.8	<0.1
Pisces	Fish (superclass)	35,601.5	6.4	<0.1
Farfantepenaeus aztecus	Brown shrimp	24,340.3	4.4	<0.1
Micropogonias undulatus	Atlantic croaker	70,947.1	12.8	<0.1
Leiostomus xanthurus	Spot (flat croaker)	29,686.0	5.4	<0.1
Invertebrate	Invertebrate	6,347.3	1.1	<0.1
Cynoscion spp.	Seatrout (genus)	11,666.5	2.1	<0.1
Stellifer lanceolatus	Star drum	10,750.4	1.9	0.1
Carybdeidae	Jellyfish (family)	11,361.6	2.1	0.1
Crustacean	Crustacean	5,235.8	0.9	0.1
Stomolophus meleagris	Cannonball jellyfish	13,979.9	2.5	0.1
Paralichthys dentatus	Summer flounder	856.0	0.2	0.1
Callinectes sapidus	Blue crab	2,912.9	0.5	0.1
Debris	Debris (rocks, logs, etc.)	2,562.1	0.5	0.1
Penaeus discard	Penaeid shrimp discard (brown,white, pink)	1,759.2	0.3	0.1
Brevoortia tyrannus	Atlantic menhaden	2,154.0	0.4	0.1
Rhizoprionodon terraenovae	Atlantic sharpnose shark	1,770.8	0.3	0.1
Centropristis philadelphica	Rock seabass	590.8	0.1	0.1
Cynoscion nothus	Silver seatrout	2,040.2	0.4	0.1
Paralichthys lethostigma	Southern flounder	660.4	0.1	0.1
Scomberomorus maculatus	Spanish mackerel	471.5	0.1	0.1
Menticirrhus saxatilis	Northern kingfish	929.4	0.2	0.1
Sphyrna tiburo	Bonnethead shark	834.3	0.2	0.1
Pomatomus saltatrix	Bluefish	370.4	0.1	0.1
Farfantepenaeus duorarum	Pink shrimp	134.0	0.0	0.1
Cynoscion regalis	Weakfish	2,780.8	0.5	0.1
Menticirrhus americanus	Southern kingfish	8,401.7	1.5	0.1
Scomberomorus cavalla	King mackerel	132.8	0.0	0.2
Sphyrna lewini	Hammerhead scalloped shark	146.4	0.0	0.2
Trachinotus carolinus	Florida pompano	35.9	0.0	0.2
Lutjanus campechanus	Red snapper	1.2	0.0	0.3
Cynoscion nebulosus	Spotted seatrout	19.7	0.0	0.3
Centropristis striata	Black seabass	3.7	0.0	0.4
Carcharhinus limbatus	Blacktip shark	67.9	0.0	0.4
Mustelus canis	Smooth dogfish shark	21.8	0.0	0.4
Centropristis ocyurus	Bank seabass	2.9	0.0	0.5
Stenotomus chrysops	Scup	0.3	0.0	0.5
Pogonias cromis	Black drum	3.3	0.0	0.5
General sharks	Sharks grouped	19.8	0.0	0.6
Carcharhinus isodon	Finetooth shark	2.9	0.0	0.7
Acipenser spp.	Sturgeon (genus)	2.3	0.0	1.0
Rachycentron canadum	Ling cobia	1.0	0.0	1.0
Alosa spp.	Herring (genus)	0.1	0.0	1.0
Sciaenops ocellatus	Red drum	8.2	0.0	1.0

debris at 1% (0.4 kg/h), and invertebrates at 1% (0.2 kg/h). All other species comprised 2% of the total weight (rounding).

CPUE and variance estimates for species selected from all sampled nets during the monitoring period in the Gulf of Mexico skimmer trawl fishery are depicted (Table 13). As expected, CV estimates for commonly caught species were low (≤0.2). Relatively higher CV estimates for several species including, but not limited to, sciaenids and sharks were detected.

Spatial CPUE density (kg/h) plots for several of these species are denoted in Figures 18–23. High-density CPUE for brown shrimp occurred in statistical areas 12 and 13 (Fig. 18), with high CPUE observed in statistical areas 15 and 16 for white shrimp (Fig. 19). High-density CPUE for Atlantic croaker occurred in relatively small concentrated cells throughout statistical areas 10–16 (Fig. 20); seatrout CPUE exhibited a similar pattern as Atlantic croaker although to a lesser degree in density (Fig. 21).

For the Gulf of Mexico skimmer trawl fishery, cluster locations of statistically significant high CPUE for penaeid shrimp were most pronounced in concentrated cells of statistical areas 13–15 (Fig. 22). For all discard (bycatch) species combined (Fig. 23), clusters of significantly high CPUE were most detectable in statistical areas 12–14 in the northwestern Gulf, with significantly lower CPUE occurring in one isolated cell off the coast in statistical area 14.

Protected Species

From January 2011 through December 2016, 158 sea turtles (67 Kemp's Ridley, 47 loggerhead, 22 green, 18 unidentified hardshell, 3 leatherback, and 1 unknown) were captured in otter and skimmer shrimp trawls (Table 14) with most (56%) documented from May to August (Fig. 24). Of the 158 sea turtles, 45 were captured in skimmer trawl nets. The remaining interactions (113) were caught in the otter trawl fishery. Of these, 62% were observed in try nets, 26% in TED-equipped nets (went through the TED grid), and 12% were caught before the TED. Most (82%) of the 158 sea turtles were released alive and conscious.

Other protected species captured aboard shrimp trawlers (Fig. 25) included five Atlantic sturgeon, three of which were released alive. Five smalltooth sawfish were captured, three of the individuals were captured on the same trip and near the same location; two were released alive with one discarded dead. The fate of the remaining two sawfish captured during the study period could not be determined.

Ten sea birds were captured, all of which were discarded dead. Three laughing gulls interacted with skimmer trawl operations. Three brown pelicans and one unidentified pelican were documented in net haul back and retrieval operations aboard shrimp otter trawlers. Two other seabirds and one songbird caught aboard otter trawlers could not be positively identified.

Four bottlenose dolphins, *Tursiops truncatus*, and one unidentified marine mammal (Family Delphinidae) were documented in the Gulf of Mexico shrimp otter trawl fishery. The bottlenose dolphins were entangled in fishing gear, primarily the lazy line, and were all freshly dead at the time of release. The unidentified marine mammal was a previously dead carcass, captured in the try net.

Discussion

Bycatch continues to be one of the most significant and multifaceted issues in fishery management (Hall et al., 2000; Hall and Mainprize, 2005; Gray and Kennelly, 2018). The adverse effects of trawling, on a regional and global scale, in terms of a reduction in biodiversity, shifts in community structure, disruption of the food web, waste, profitability, user conflicts, and mortality of undersized target and nontarget species, inclusive of protected species, have been well documented (Alverson et al., 1994; Hall, 1996; Greenstreet and Rogers, 2000; Hall et al., 2000; Murawski et al., 2000; NRC, 2002; Chuenpagdee et al., 2003; Diamond, 2004; Kumar and Deepthi, 2006). Tropical shrimp trawl fisheries accounted for 27% of global discards as reported by Kelleher (2005). Moreover, an estimated 1.06 million tons of marine fish were discarded in 2002 in U.S. fisheries, ranking the United States one of the highest worldwide relative to discards (Harrington et al., 2005).

Based on findings from the current (2011–16) mandatory observer program, estimated overall CPUE for the shrimp fishery by region was comparable to those reported in Scott-Denton et al. (2012), and similar in some respects to earlier bycatch estimations conducted for the Gulf of Mexico, but markedly different for the South Atlantic (Scott-Denton and Nance, 1996; Nance and Scott-Denton, 1997; Scott-Denton, 2007; NMFS[2,3]; Nance et al.[6]). For the 1992 through 1996 period, overall catch rates were 28.0 kg/h in the Gulf of Mexico, and 27.0 kg/h in the South Atlantic penaeid fisheries (NMFS[3]). Scott-Denton (2007) reported catch rates of 30.8 kg/h in the Gulf of Mexico and 27.7 kg/h in the South Atlantic from 1992 through 2005. Scott Denton et al. (2012) estimated overall CPUE as 34.3 kg/h for the Gulf of Mexico and 51.8 kg/h in the South Atlantic for 2007 through 2010. In this study, CPUE was 31.5 kg/h for the Gulf of Mexico and 52.0 kg/h in the South Atlantic, and relatively consistent with Scott-Denton et al. (2012).

Table 12.—Selected fish species recorded from all rock shrimp nets from bycatch characterization samples, based on mandatory observer coverage from January 2011 through December 2016.

Scientific name	Common name	Extrapolated weight (kg)	Kg/h	CV
Acipenser spp.	Sturgeon (genus)	0.0	0.0	0.0
Alosa spp.	Herring (genus)	0.0	0.0	0.0
General sharks	Sharks grouped	0.0	0.0	0.0
Carcharhinus brevipinna	Spinner shark	0.0	0.0	0.0
Carcharhinus falciformis	Silky shark	0.0	0.0	0.0
Carcharhinus isodon	Finetooth shark	0.0	0.0	0.0
Carcharhinus limbatus	Blacktip shark	0.0	0.0	0.0
Cynoscion nebulosus	Spotted seatrout	0.0	0.0	0.0
Cynoscion regalis	Weakfish	0.0	0.0	0.0
Menticirrhus americanus	Southern kingfish	0.0	0.0	0.0
Mustelus canis	Smooth dogfish shark	0.0	0.0	0.0
Mycteroperca microlepis	Gag	0.0	0.0	0.0
Penaeid shrimp (brown,white, pink)	Penaeid shrimp (brown,white, pink)	0.0	0.0	0.0
Pogonias cromis	Black drum	0.0	0.0	0.0
Rhizoprionodon terraenovae	Atlantic sharpnose shark	0.0	0.0	0.0
Sciaenops ocellatus	Red drum	0.0	0.0	0.0
Sphyrna lewini	Hammerhead scalloped shark	0.0	0.0	0.0
Sphyrna tiburo	Bonnethead shark	0.0	0.0	0.0
Stenotomus chrysops	Scup	0.0	0.0	0.0
Trachinotus carolinus	Florida pompano	0.0	0.0	0.0
Pisces	Fish (superclass)	14,653.9	14.0	<0.1
Sicyonia spp.	Rock (genus) shrimp	23,659.6	22.7	<0.1
Syacium papillosum	Dusky flounder	3,781.6	3.6	0.1
Synodus foetens	Inshore lizardfish	4,685.8	4.5	0.1
Invertebrate	Invertebrate	5,050.6	4.8	0.1
Sicyonia discards	Rock (discards) shrimp	1,097.3	1.1	0.1
Farfantepenaeus aztecus	Brown shrimp	861.2	0.8	0.1
Crustacean	Crustacean	2,592.4	2.5	0.1
Centropristis ocyurus	Bank seabass	785.6	0.8	0.1
Portunus spinicarpus	Longspine swimming crab	3,891.6	3.7	0.1
Centropristis philadelphica	Rock seabass	1,123.7	1.1	0.1
Farfantepenaeus duorarum	Pink shrimp	1,139.1	1.1	0.1
Debris	Debris (rocks, logs, etc.)	1,267.0	1.2	0.1
Portunus gibbesii	Iridescent swimming crab	422.0	0.4	0.2
Penaeus discard	Penaeid shrimp discard (brown,white, pink)	15.1	0.0	0.2
Leiostomus xanthurus	Spot (flat croaker)	806.7	0.8	0.2
Menticirrhus saxatilis	Northern kingfish	81.5	0.1	0.2
Litopenaeus setiferus	White shrimp	16.2	0.0	0.3
Micropogonias undulatus	Atlantic croaker	169.9	0.2	0.3
Paralichthys lethostigma	Southern flounder	47.2	0.0	0.3
Centropristis striata	Black seabass	22.3	0.0	0.3
Paralichthys dentatus	Summer flounder	47.6	0.0	0.4
Cynoscion spp.	Seatrout (genus)	43.8	0.0	0.5
Lutjanus campechanus	Red snapper	0.3	0.0	0.6
Rachycentron canadum	Ling cobia	11.0	0.0	0.7
Pomatomus saltatrix	Bluefish	4.3	0.0	1.0
Scomberomorus cavalla	King mackerel	2.5	0.0	1.0
Scomberomorus maculatus	Spanish mackerel	1.5	0.0	1.0
Cynoscion nothus	Silver seatrout	2.4	0.0	1.0

In comparison to earlier studies on the magnitude of bycatch in southeastern shrimp fishery, more recent years data depict declining trends in the amount of nontarget catch. Alverson et al. (1994) reported a discard to landing ratio of 10.30 and 8.00 for the Gulf of Mexico and South Atlantic shrimp fisheries, respectively. Harrington et al. (2005) and Kelleher (2005) revealed lower ratios in more recent assessments, although estimation methods varied. Scott-Denton (2007) calculated discards to landings ratios of 5.18 and 3.20 for the Gulf of Mexico and South Atlantic, respectively, from 1992 through 2005; slightly higher than estimates of 4.56 and 2.95 reported by Harrington et al. (2005) for 1992 through 1996 for the same areas. Scott-Denton et al. (2012) reported substantially lower bycatch ratios at 2.47 in the Gulf of Mexico and 4.25 in the South Atlantic. In the current study, for these same areas, bycatch ratios were 2.54 and 3.50, respectively. While these ratios are similar to the rates observed during 2007–10, both are considerably lower than the bycatch ratios documented in the pre-TED, pre-BRD, high-effort years (e.g., Alverson et al. (1994) reported bycatch to shrimp ratio for the Gulf penaeid shrimp fishery was 10.3).

Scott-Denton et al. (2012) attribute these differences for the Gulf of Mexico by examining percent composition by species categories that reflect a rise in shrimp CPUE and a substantial decline in shrimp effort (Galla-

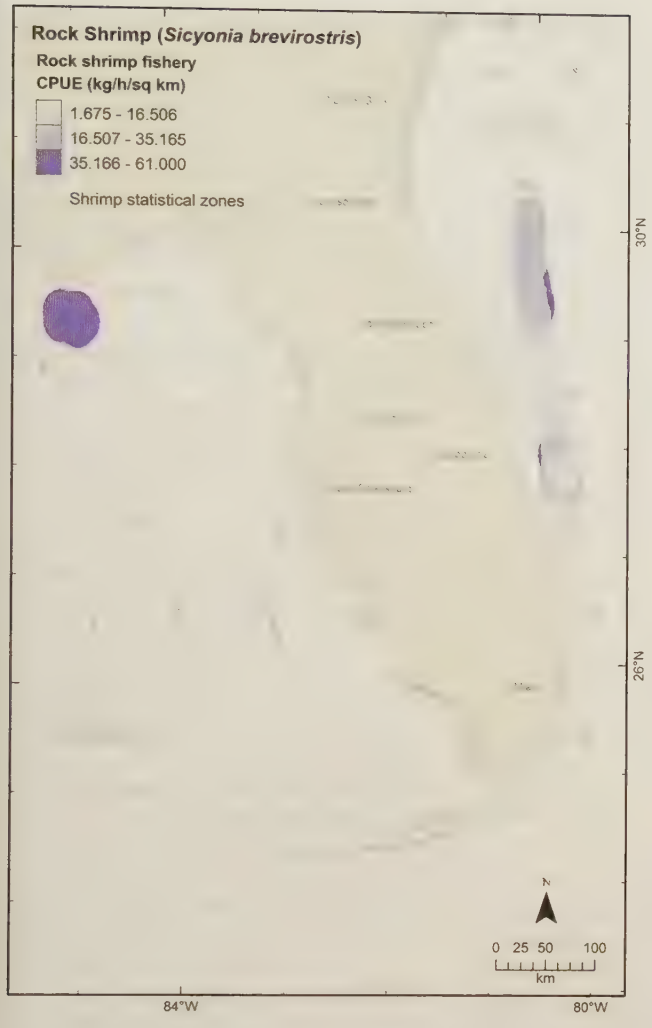

Figure 14.—CPUE density surface for rock shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern rock shrimp fishery from January 2011 through December 2016.

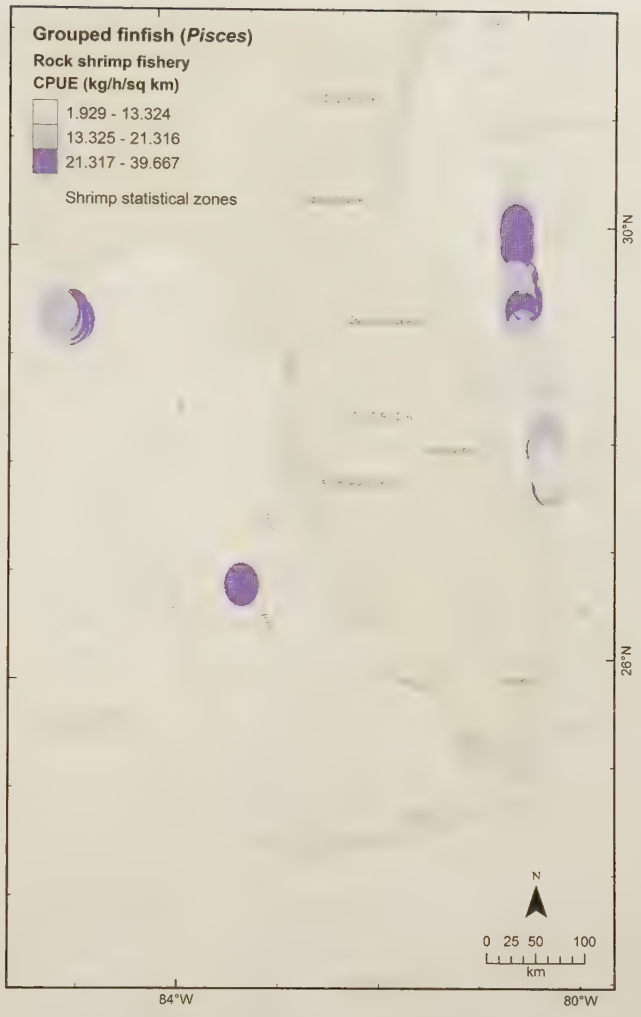

Figure 15.—CPUE density surface for grouped finfish by area and target, based on mandatory observer coverage of the U.S. southeastern rock shrimp fishery from January 2011 through December 2016.

way et al., 2003; Nance et al., 2008). Based on Gulf of Mexico shrimp landings and effort data from 1981 through 2016 (Hart[15]), an increasing trend in shrimp CPUE has been observed since 2002. Conversely, shrimp effort has been decreasing since 2002 as well as the number of federally permitted vessels (SERO[9]). And finally, the mandate for TED's and BRD's over the past decades has reduced primarily large bycatch (e.g., sharks, and many other, but not all, fish and sea turtles).

[15]Hart, R. 2017. Unpubl. data on file at National Marine Fisheries Service, NOAA, Galveston Laboratory, Galveston, TX 77551

Helies and Jamison[8] reported that the lower finfish to shrimp ratios in the Gulf of Mexico may be due to basic weight differences between shrimp and fish taken currently in the fishery as compared with earlier years. The authors conclude that an increase abundance in nearshore sciaenids since 2002, resulting from decreases in shrimp fishing effort, combined with more effective exclusion by new BRD designs may have brought about the change in finfish to shrimp ratios in recent years.

In the South Atlantic from 1992 through 1996, estimated percent catch composition for finfish species was at 51%, and 18% for commercial shrimp species (NMFS[3]). Scott-Denton (2007) calculated finfish species at 47% (13.0 kg/h), followed by penaeid shrimp at 24% (6.6 kg/h) for the 1992 through 2005 voluntary observer program. Scott-Denton et al. (2012), in the 2007 through 2010 mandatory observer program, reported that finfish accounted for 60% (31.2 kg/h) of the catch with penaeid shrimp at 19% (9.9 kg/h), which revealed an increase in shrimp CPUE and over a two-fold increase in finfish CPUE. This is similar as in the current study with finfish compris-

Table 13.—Selected Gulf of Mexico fish species recorded from all skimmer shrimp nets from bycatch characterization samples, based on mandatory observer coverage from January 2011 through December 2016.

Scientific name	Common name	Extrapolated weight (kg)	Kg/h	CV
General sharks	Sharks grouped	0.0	0.0	0.0
Carcharhinus acronotus	Blacknose shark	0.0	0.0	0.0
Carcharhinus brevipinna	Spinner shark	0.0	0.0	0.0
Carcharhinus isodon	Finetooth shark	0.0	0.0	0.0
Farfantepenaeus duorarum	Pink shrimp	0.0	0.0	0.0
Lutjanus campechanus	Red snapper	0.0	0.0	0.0
Lutjanus spp.	Snapper (genus)	0.0	0.0	0.0
Mustelus canis	Smooth dogfish shark	0.0	0.0	0.0
Mustelus norrisi	Florida smoothhound shark	0.0	0.0	0.0
Negaprion brevirostris	Lemon shark	0.0	0.0	0.0
Rhomboplites aurorubens	Vermilion (B-liner) snapper	0.0	0.0	0.0
Sicyonia spp.	Rock (genus) shrimp	0.0	0.0	0.0
Sicyonia brevirostris	Brown rock shrimp	0.0	0.0	0.0
Sicyonia discards	Rock (discards) shrimp	0.0	0.0	0.0
Stenotomus caprinus	Longspine porgy	0.0	0.0	0.0
Farfantepenaeus aztecus	Brown shrimp	7,575.0	11.8	<0.1
Pisces	Fish (superclass)	8,163.3	12.8	<0.1
Micropogonias undulatus	Atlantic croaker	2,473.6	3.9	<0.1
Cynoscion spp.	Seatrout (genus)	343.1	0.5	0.1
Crustacean	Crustacean	986.9	1.5	0.1
Litopenaeus setiferus	White shrimp	2,249.4	3.5	0.1
Cynoscion nebulosus	Spotted seatrout	65.2	0.1	0.1
Paralichthys lethostigma	Southern flounder	48.2	0.1	0.2
Invertebrate	Invertebrate	137.7	0.2	0.2
Penaeid shrimp (brown,white, pink)	Penaeid shrimp (brown,white, pink)	780.4	1.2	0.2
Scomberomorus maculatus	Spanish mackerel	69.4	0.1	0.2
Debris	Debris (rocks, logs, etc.)	279.7	0.4	0.2
Penaeus discard	Penaeid shrimp discard (brown,white, pink)	43.9	0.1	0.3
Carcharhinus limbatus	Blacktip shark	48.1	0.1	0.4
Rhizoprionodon terraenovae	Atlantic sharpnose shark	26.2	0.0	0.4
Pogonias cromis	Black drum	32.5	0.1	0.6
Sciaenops ocellatus	Red drum	6.1	0.0	0.6
Sphyrna tiburo	Bonnethead shark	1.6	0.0	0.7
Scomberomorus cavalla	King mackerel	0.3	0.0	0.8
Rachycentron canadum	Ling cobia	0.2	0.0	0.9
Lutjanus synagris	Lane snapper	3.8	0.0	1.0

ing 63% (32.8 kg/h) of the catch and penaeid shrimp at 22% (11.6 kg/h). A very plausible explanation for the increase in finfish CPUE may be attributable to different fishing patterns between the volunteer and mandatory observer programs resulting in shifts of the dominant species observed.

In the South Atlantic rock shrimp fishery, Scott-Denton et al. (2012) reported an increase in percent composition of rock shrimp at 41% (29.0 kg/h) as compared with the 2001 to 2006 period with rock shrimp comprising 19% (8.7 kg/h) of the catch (SAFMC[16]). During the current study, vessels that fished in both the Gulf and South Atlantic with rock shrimp accounting for 37% (23.7 kg/h), a slight decline and possibly attributed to areas fished.

Scott-Denton et al. (2012) characterized shifts in dominant species and rates for longspine porgy, *Stenotomus caprinus*, and Atlantic croaker during voluntary vs. mandatory programs. In the voluntary program (1992 through 2005), longspine porgy and Atlantic croaker comprised the largest percentage of the overall catch in the Gulf of Mexico with estimated CPUE (kg/h) at 2.8 and 2.1, respectively (Scott-Denton, 2007). Scott-Denton et al. (2012) reported CPUE (kg/h) for Atlantic croaker at 5.4 and 1.4 for longspine porgy in the mandatory program. Scott-Denton et al. (2012) attributed this shift in dominant species and rates to the mandatory nature of vessel selection and areas fished (nearshore vs. offshore). In the voluntary study, a large number of vessel operators who participated fished primarily in offshore waters (Scott-Denton, 2007). Similarly, with respect to the dominant species in South Atlantic from 1992 through 2005, CPUE (kg/h) for Atlantic croaker was 3.6 and 3.4 for spot (Scott-Denton, 2007). In the mandatory program, CPUE (kg/h) was substantially higher for Atlantic croaker at 12.5 and comparable for spot at 3.8 (Scott-Denton et al., 2012). This is similar to the current assessment with CPUE (kg/h) for Atlantic croaker at 12.8 and slightly higher for spot at 5.4

Scott-Denton et al. (2012) reported that while several species listed as overfished or undergoing overfishing did not comprise a large percentage by weight of the total bycatch, the number of individuals discarded combined with the amount of annual shrimp effort exerted may be reason for significant consideration. Analysis of data from three observer programs and federal and state resource surveys was used to provide annual estimates for selected species of finfish bycatch in the commercial Gulf of Mexico shrimp trawl fishery (Nichols et al.[1,17] and Nichols and Pellegrin[18]). The findings revealed that while the magnitude of species common in shrimp trawl bycatch was not unpredicted, the projected estimate for the less frequently encountered species such as red snapper, king mackerel, *Scomberomorus cavalla*, and Spanish mackerel, *Scomberomorus maculatus*, was similar to, or exceeded, the recreational take (Nichols et al.[1]). Red snapper, one of the most high-profile species, accounted for approximately 0.3% of the total catch by weight in the Gulf of Mexico in 1992 through 2005 (Scott-Denton, 2007). This estimate remained the same (0.3%) as reported by both Scott-Denton et al. (2012) and the current study (0.3%). This is further supported by Helies and Jamison[8], who inferred that while there have been increasing trends in the abundance of Atlantic croaker and inshore lizardfish in recent years, abundance levels for longspine porgy and juvenile red

[16]SAFMC. 2008. Observer Coverage of the US Southeastern Atlantic Rock Shrimp Fishery, September 2001 through September 2006 Preliminary Report. South Atl. Fish. Manage. Counc., Charleston, S.C. (avail. at http://www.safmc.net).

[17]Nichols, S., A. Shah, G. J. Pellegrin, and K. Mullin. 1990. Updated estimates of shrimp fleet bycatch in the offshore waters of the U.S. Gulf of Mexico. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Pascagoula, Miss., 22 p.

[18]Nichols, S., and G. J. Pellegrin, Jr. 1992. Revision and update of estimates of shrimp fleet bycatch 1972–1991. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Southeast Fish. Sci. Cent., Pascagoula, Miss., 17 p.

Figure 16.—Hot Spot Analysis for rock shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern rock shrimp fishery from January 2011 through December 2016.

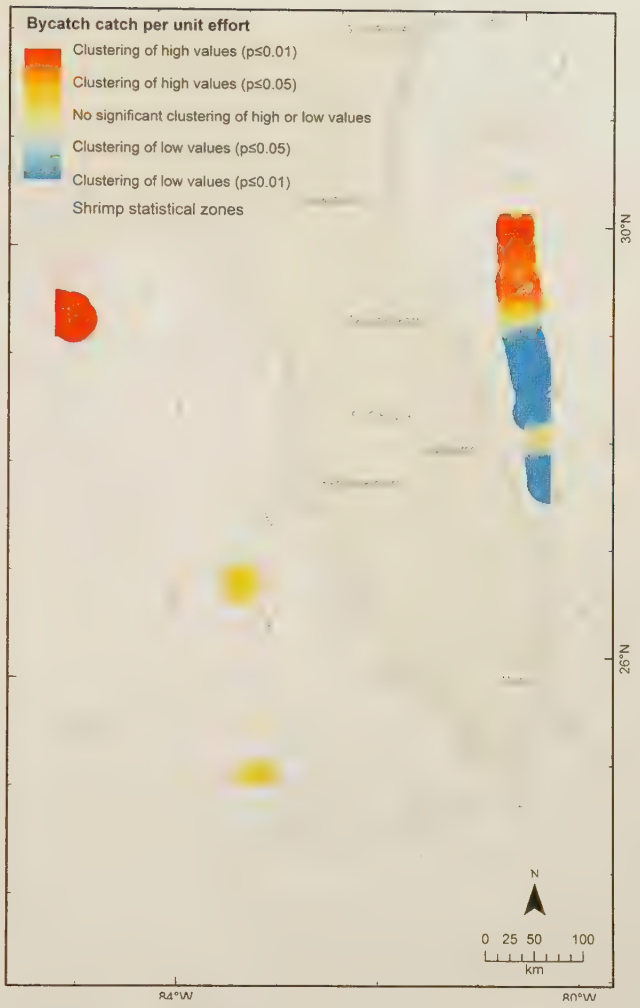

Figure 17.—Hot Spot Analysis for discard (bycatch) species by area and target, based on mandatory observer coverage of the U.S. southeastern rock shrimp fishery from January 2011 through December 2016.

snapper have remained relatively consistent.

Recent literature (Gazey et al., 2008; Gallaway et al., 2009; Gazey et al., 2014; Gallaway et al., 2017; SEDAR 52[19]) addresses current estimates of red snapper life history, mortality, and the effects of trawl mortality on the red snapper stock. These authors agree that shrimp trawl bycatch consists mainly of age 0 and age 1 red snapper, with a minimal number of age 2 fish. Gallaway et al. (2017) concluded that natural mortality of young red snapper is much higher (four times) than was thought to be the case in the late 1980's and early 1990's with bycatch mortality estimated to be only 4%. It was suggested that life history attributes of those species that have not increased in abundance in response to decreased shrimp and bycatch reduction efforts be examined to provide possible explanations.

Mandatory observer coverage for the skimmer trawl fishery began in 2012 (Pulver et al., 2012: Scott-Denton et al., 2014) and has continued at varying levels of coverage to increase the amount of information available on the fishery, particularly to document sea turtle interactions. A total of 45 sea turtles were captured ranging from a high number (24) in 2011 to a low (3) in 2016; however, coverage levels by year have declined primarily due to vessel compliance (Scott-Denton et al., 2014).

Bycatch became a major management issue resulting from the rapid growth in fisheries worldwide, increasing user competition, and the rise of environmental issues and subsequent global efforts to minimize the

[19]SEDAR (Southeast Data, Assessment and Review) 52. 2018. Gulf of Mexico Red Snapper Stock Assessment Report. SEDAR, Charleston, South Carolina.

Table 14.—Sea turtle interactions by net type, species, capture condition, and project for all tows based mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

	Gulf mandatory penaeid			South Atlantic mandatory penaeid			Mandatory rock			Gulf mandatory skimmer			Total		
Project	Total	Condition	Total tow time (h)	Total	Condition	Total tow time (h)	Total	Condition	Total tow time (h)	Total	Condition	Total tow time (h)	Species interactions	Sea turtle condition	Tow time (h)
Standard Net	36		102,443.1	7		5,111.0			681.4	45		3,152.8	88		111,388.4
Green	11			1						4			16		
Alive		2			1						1			4	
Fresh dead/comatose/unresponsive		9									2			11	
Previously dead											1			1	
Kemp's ridley	15			1						36			52		
Alive		5			1						33			39	
Fresh dead/comatose/unresponsive		10									2			12	
Previously dead											1			1	
Leatherback	3												3		
Alive		2												2	
Fresh dead/comatose/unresponsive		1												1	
Loggerhead				1						4			5		
Alive					1						4			5	
Unidentified hardshell	7			4						1			12		
Alive		2			3						1			6	
Fresh dead/comatose/unresponsive		3												3	
Unknown		2			1									3	
Try Net	46		31,441	21		4,342	3		284				70		36,067
Green	5			1									6		
Alive		5			1									6	
Kemp's ridley	9			6									15		
Alive		9			6									15	
Loggerhead	25			14			3						42		
Alive		24			14			3						41	
Fresh dead/comatose/unresponsive		1												1	
Unidentified hardshell	6												6		
Alive		5												5	
Unknown		1												1	
Unknown	1												1		
Unknown		1												1	
Total	82			28			3			45			158		

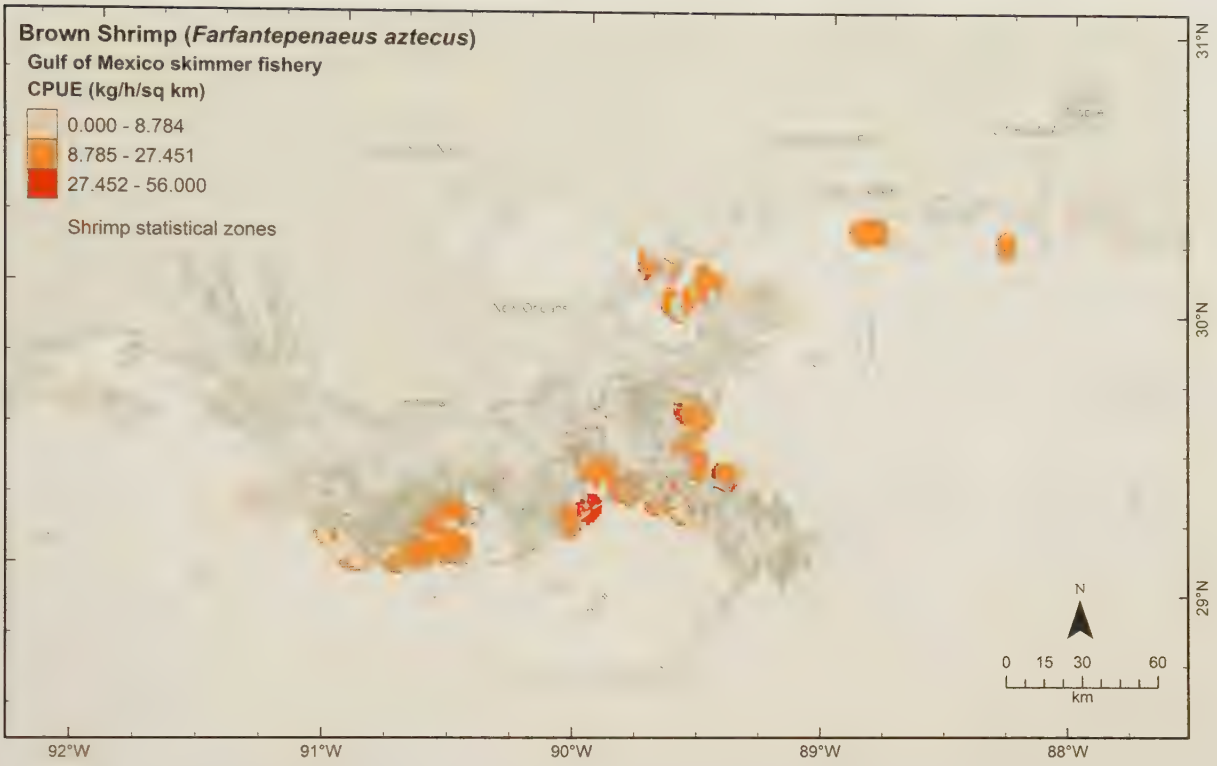

Figure 18.—CPUE density surface for brown shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern skimmer trawl shrimp fishery from January 2011 through December 2016.

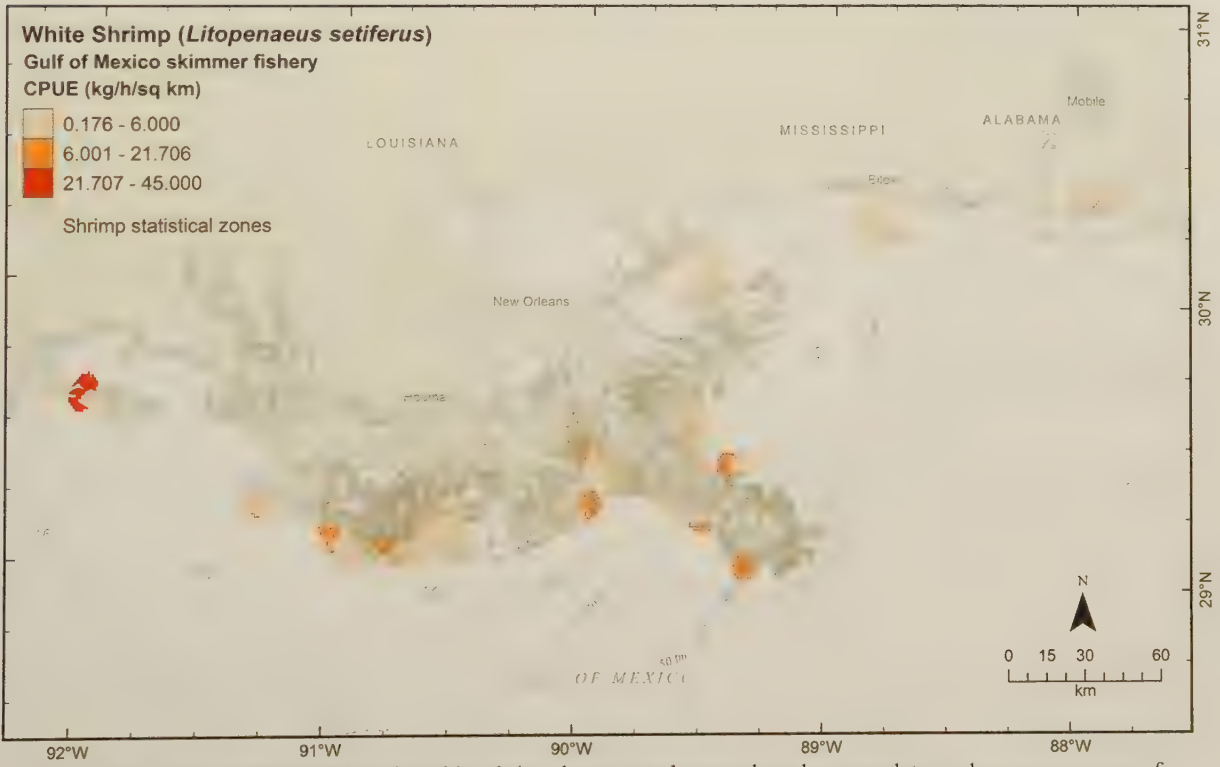

Figure 19.—CPUE density surface for white shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern skimmer trawl shrimp fishery from January 2011 through December 2016.

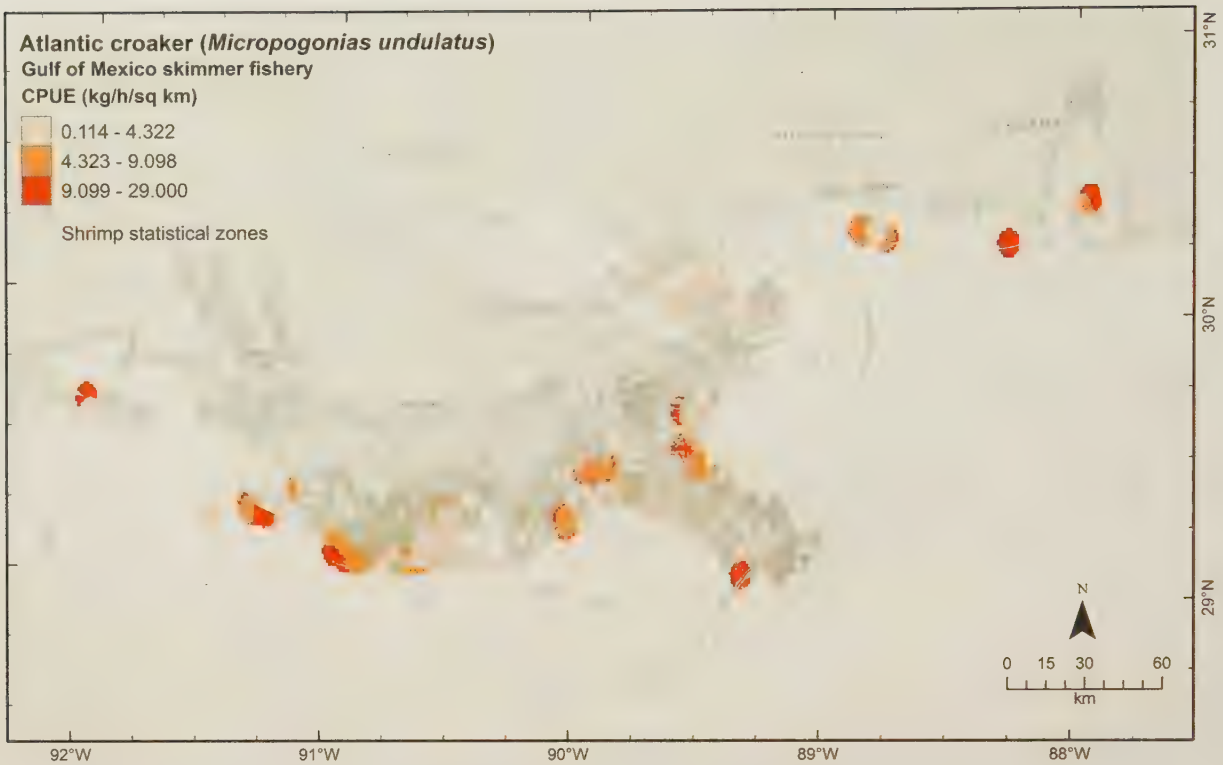

Figure 20.—CPUE density surface for Atlantic croaker by area and target, based on mandatory observer coverage of the U.S. southeastern skimmer trawl shrimp fishery from January 2011 through December 2016.

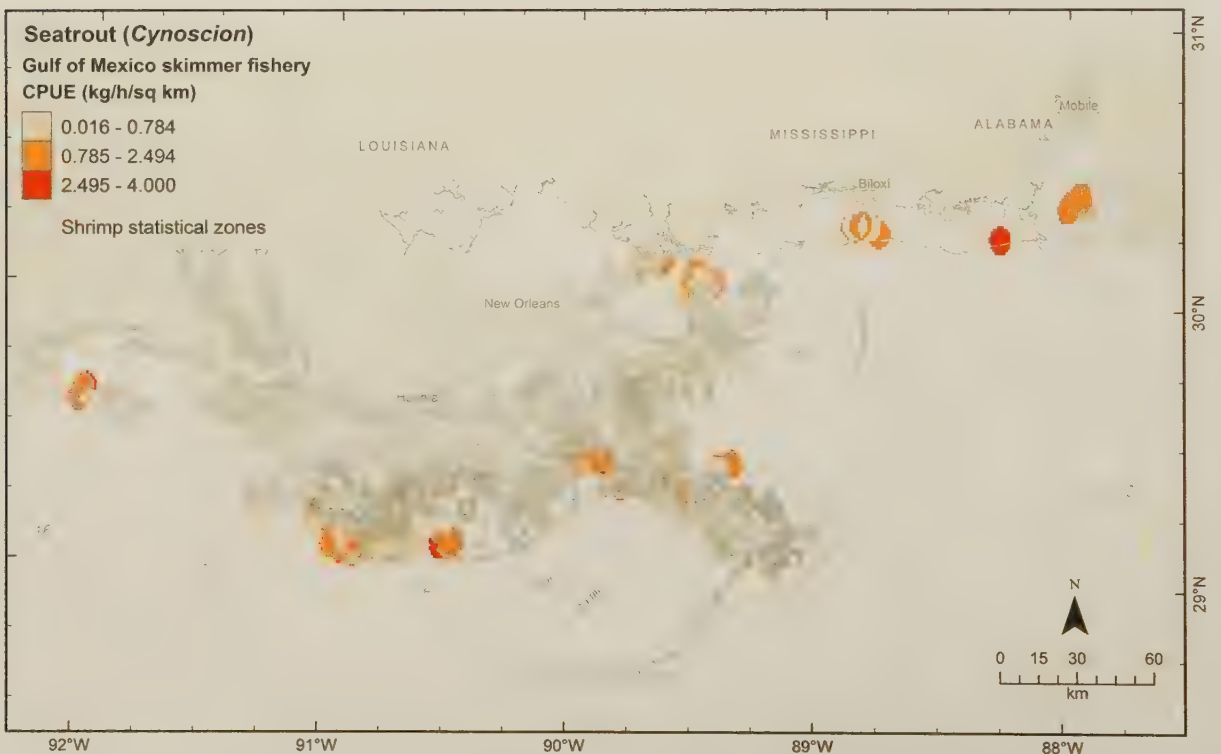

Figure 21.—CPUE density surface for seatrout by area and target, based on mandatory observer coverage of the U.S. southeastern skimmer trawl shrimp fishery from January 2011 through December 2016.

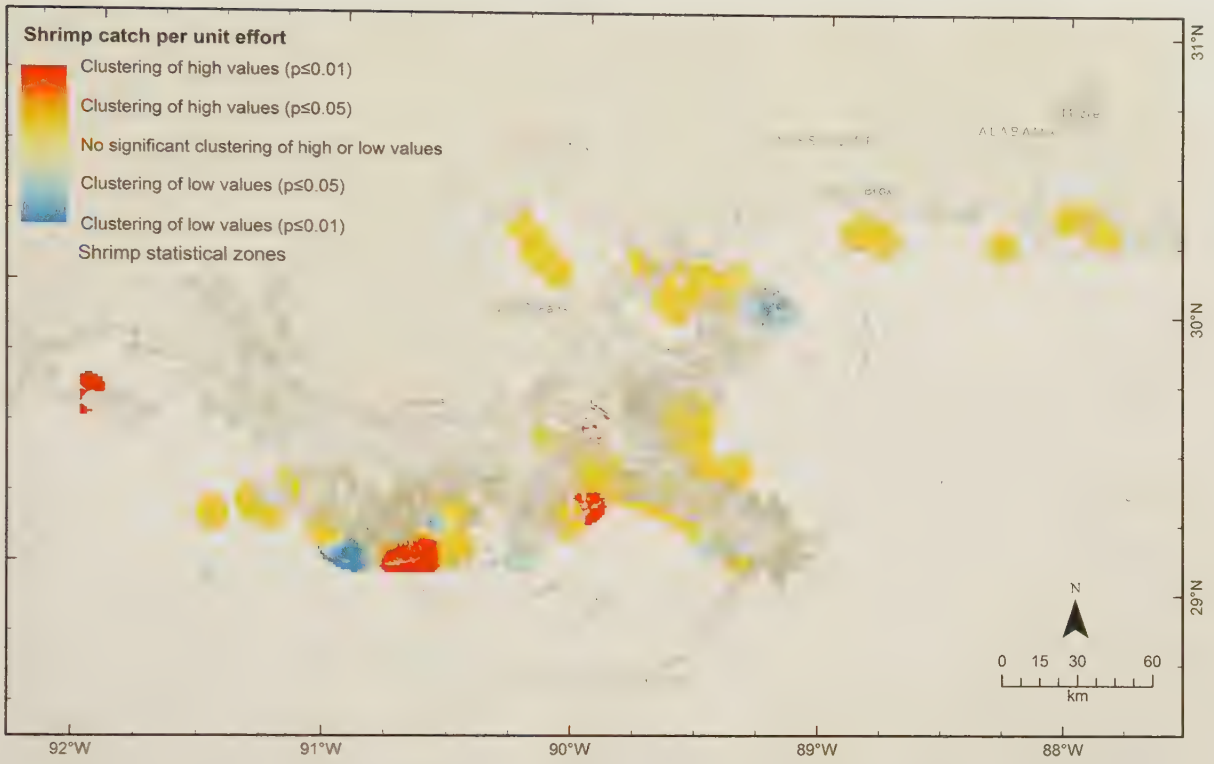

Figure 22.—Hot Spot Analysis for shrimp by area and target, based on mandatory observer coverage of the U.S. southeastern skimmer trawl shrimp fishery from January 2011 through December 2016.

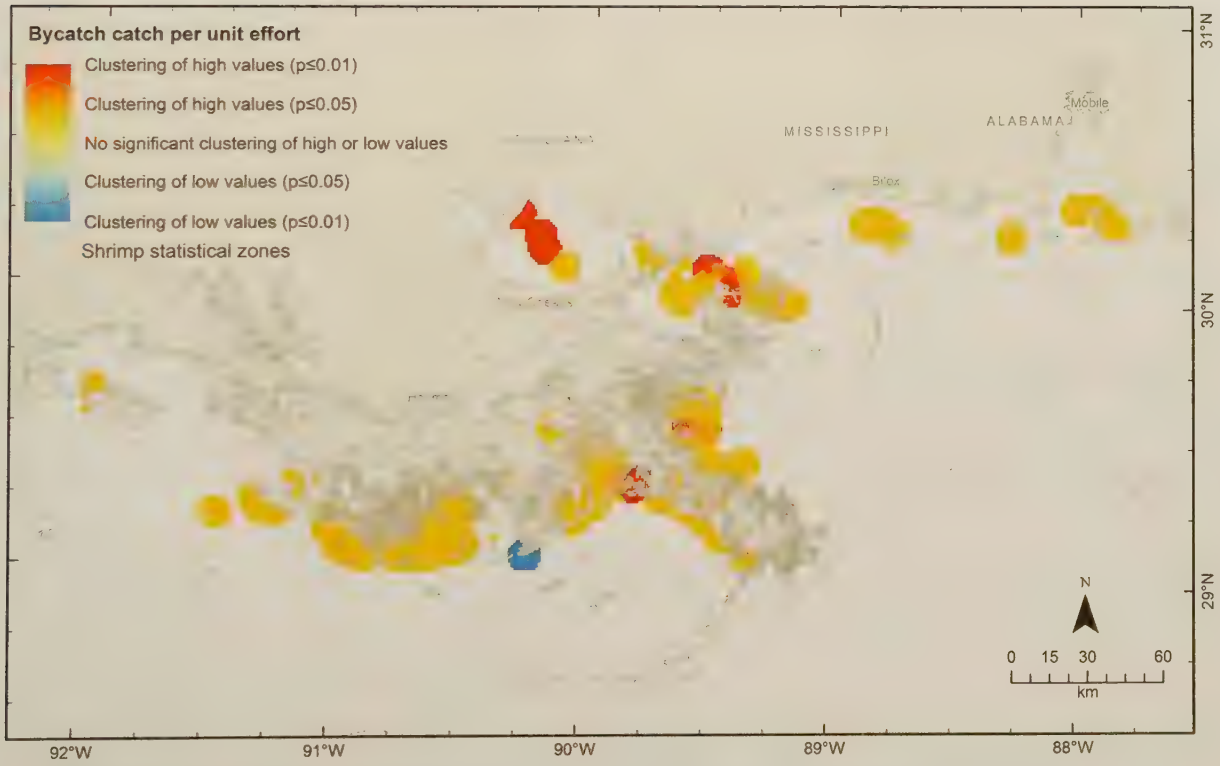

Figure 23.—Hot Spot Analysis for discard (bycatch) species by area and target, based on mandatory observer coverage of the U.S. southeastern skimmer trawl shrimp fishery from January 2011 through December 2016.

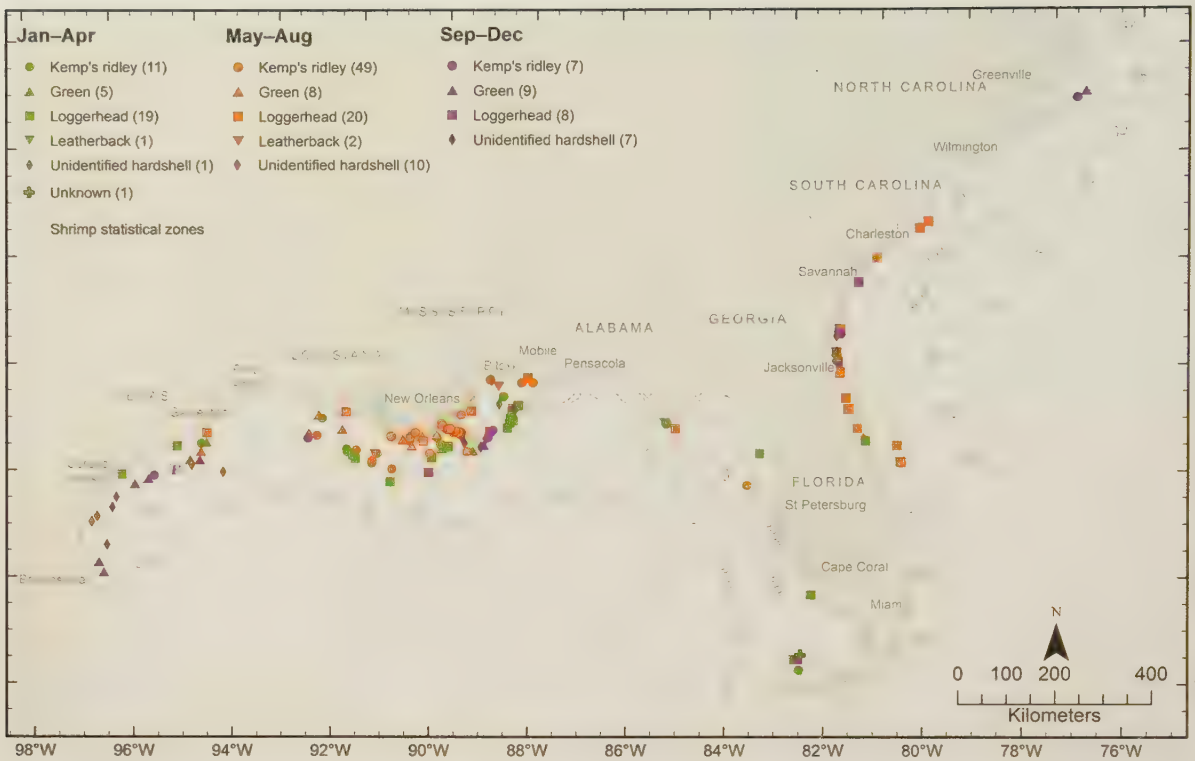

Figure 24.—Locations and dates of sea turtle captures, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

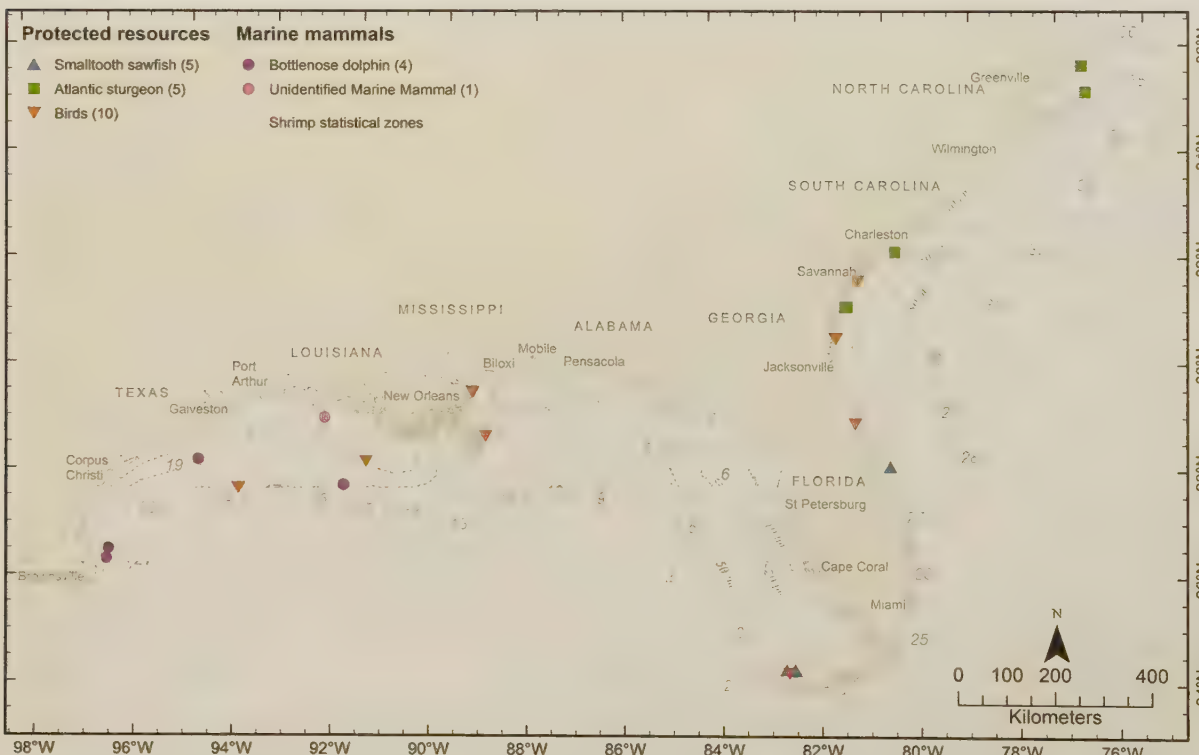

Figure 25.—Locations of protected species captures, based on mandatory observer coverage of the U.S. southeastern shrimp fishery from January 2011 through December 2016.

effects of commercial fishing operations on protected species (Alverson and Hughes, 1996).

In the southeastern United States, the incidental capture of endangered and threatened sea turtles was brought to the forefront primarily by a TED study conducted by Henwood and Stunz (1987) who estimated sea turtle catch rates to be more than 10,000 sea turtles from 1973 to 1984. Sea turtle mortality resulting from trawling operations in the southeastern shrimp fishery was determined to be the major source of man-induced mortality on loggerhead and Kemp's ridley sea turtles, resulting in higher mortality than in all other fisheries combined (Magnuson et al., 1990). Since the 1980's, substantial progress has been made to reduce sea turtle interactions, primarily through the required use of TED's and subsequent modifications (Epperly et al., 2002; Epperly and Teas, 2002) as well as other time and area management strategies. Finkbeiner et al. (2011) examined mean annual sea turtle bycatch and mortality for the U.S. Gulf and South Atlantic shrimp fishery pre-regulation (pre-2003) and post-regulation (post-2003 TED enlargements) and reported 340,500 and 133,400 sea turtles, respectively, acknowledging the reduction was not solely due to TED regulations but in large part due to the decrease in fleet effort.

Advances in TED and BRD research and design as well as management efforts have been, and are being, evaluated for other protected species and finfish stocks as well. TED's exclude large fish such as blacknose sharks, *Carcharhinus acronotus*, (Raborn et al., 2012). While BRD's do not reduce red snapper bycatch to any appreciable degree, they do reduce overall total finfish bycatch by 30% (Helies and Jamison[20]). Further, Amendment 14 to the Gulf of Mexico Fishery Council's (GMFMC) Shrimp Management Plan (GMFMC[21]) reduced red snapper bycatch in the Gulf by a mandatory offshore fisheries effort reduction initially 74% and presently 67%. These beneficial effects of TED's in offshore waters have not been offset by a substantial shrimp loss (~ 6%, Gallaway et al., 2008). These are a few of the major actions that address the negative impacts of trawling in the U.S. southeastern shrimp fisheries.

Observer programs remain the most reliable means for monitoring commercial fisheries to date by providing unbiased, reliable, and high-quality data. Findings from these programs provide insight on finfish and protected species CPUE, as well as life history characteristics for both target and nontarget species. Moreover, they provide a wide array of other variables of interest to fishery managers, the fishing industry, academia, and the public including discard levels, gear effectiveness, temporal and spatial shrimping patterns, socio-economic considerations as related to industry, and individual fishing quota program effectiveness.

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Literature Cited

Alverson, D. L., and S. E. Hughes. 1996. Bycatch: from emotion to effective natural resource management. Rev. Fish Biol. Fish. 6(4):443–462 (doi: https://doi.org/10.1007/BF00164325).

_____, M. H. Freeberg, S. A. Murawski, and J. G. Pope. 1994. A global assessment of fisheries bycatch and discards. FAO Fish. Tech. Pap. 339, 235 p.

Anderson, W. W. 1956. Observations upon the biology, ecology and life history of the common shrimp, *Penaeus setiferus* (Linnaeus) along the South Atlantic and Gulf Coasts of the United States. Proc. Indo-Pac. Fish. Counc. 6:399–403.

Chuenpagdee, R., L. E. Morgan, S. M. Maxwell, E. A. Norse, and D. Pauly. 2003. Shifting gears: assessing collateral impacts of fishing methods in U.S. waters. Front. Ecol. Environ. 1(10):517–524 (doi: https://doi.org/10.1890/1540-9295(2003)001[0517:SGACIO]2.0.CO;2).

Diamond, S. L. 2004. Bycatch quotas in the Gulf of Mexico shrimp trawl fishery: can they work? Rev. Fish Biol. Fish. 14:207–237 (doi: https://doi.org/10.1007/s11160-004-7121-0).

Epperly, S., L. Avens, L. Garrison, T. Henwood, W. Hoggard, J. Mitchell, J. Nance, J. Poffenberger, C. Sasso, E. Scott-Denton, and C. Yeung. 2002. Analysis of sea turtle bycatch in the commercial shrimp fisheries of southeast U.S. waters and the Gulf of Mexico. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-490, 88 p.

Epperly, S. P., and W. G. Teas. 2002. Turtle excluder devices—are the escape openings large enough? Fish. Bull. 100:466–474.

Finkbeiner, E. M., B. P. Wallace, J. E. Moore, R. L. Lewison, L. B. Crowder, and A. J. Nead. 2011. Cumulative estimates of sea turtle bycatch and mortality in USA fisheries between 1990 and 2007. Biol. Conserv. 144:2,719–2,727 (doi: https://doi.org/10.1016/j.biocon.2011.07.033).

Gallaway, B. J., J. G. Cole, L. R. Martin, J. M. Nance, and M. Longnecker. 2003. An evaluation of an electronic logbook as a more accurate method of estimating spatial patterns of trawling effort and bycatch in the Gulf of Mexico shrimp fishery. N. Am. J. Fish. Manage. 23:787–809 (doi: https://doi.org/10.1577/M02-105).

_____, J. G. Cole, J. M. Nance, R. A. Hart, and G. L. Graham. 2008. Shrimp loss associated with turtle excluder devices: Are historical estimates statistically biased? N. Am. J. Fish. Manage. 28:203–211 (doi: https://doi.org/10.1577/M07-002.1).

_____, S. T. Szedlmayer, and W. J. Gazey. 2009. A life history review for red snapper in the Gulf of Mexico with an evaluation of the importance of offshore petroleum platforms and other artificial reefs. Rev. Fish. 17:1–18 (doi: https://doi.org/10.1080/10641260802160717).

_____, W. J. Gazey, and J. C. Cole. 2017. An updated description of the benefits and consequences of red snapper shrimp trawl bycatch actions in the Gulf of Mexico. N. Am. J. Fish. Manage. (2):414–419 (doi: https://doi.org/10.1080/02755947.2016.1271842).

Gazey, W. J, B. J. Gallaway, J. G. Cole, and D. A. Fournier. 2008. Age composition, growth, and density-dependent mortality in juvenile red snapper estimated from observer data from the Gulf of Mexico penaeid shrimp fishery. N. Am. J. Fish. Manage. 28:1,828–1,842 (doi: https://doi.org/10.1577/M07-216.1).

_____, _____, _____, and _____. 2014. Accounting for fishing mortality when comparing density-dependent with density-independent mortality in Gulf of Mexico red snapper: response to comment. N. Am. J. Fish. Manage. 34(2):352–358 (doi: https://doi.org/10.1080/02755947.2014.880763).

Gray, C. A., and S. J. Kennelly. 2018. Bycatches of endangered, threatened and protected species in marine fisheries. Rev. Fish Biol. Fish. 28:521 (doi: https://doi.org/10.1007/s11160-018-9520-7).

[20]Helies, F. C. and J. L. Jamison. 2010. Industry/National Marine Fisheries Service Bycatch Reduction Device Workshop. Final report of the Gulf and South Atlantic Fisheries Foundation prepared under NOAA Award NA08NMF4540398 (avail. at http://www.gulfsouthfoundation.org/research/completed).

[21]GMFMC. 2008. Amendment 14 to the Shrimp Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico. Gulf Mex. Fish Manage. Counc., Tampa, Fla. (avail. at http://www.gulfcouncil.org).

Greenstreet, S. P. R., and S. I. Rogers. 2000. Effects of fishing on non-target fish species. *In* M. J. Kaiser and S. de Groot (Editors), Effects of fishing on non-target species and habitats: biological, conservation and socio-economic issues, p. 217–234. Blackwell Sci., Oxford.

Hall, M. A. 1996. On bycatches. Rev. Fish Biol. Fish. 6:319–352 (doi: https:/doi.org/10.1007/BF00122585).

Hall, M. H., D. L. Alverson, and K. I. Metuzals. 2000. By-catch: problems and solutions. Mar. Pollut. Bull. 41(1–6):204–219 (doi: https://doi.org/10.1016/S0025-326X(00)00111-9).

Hall, S. J., and B. M. Mainprize. 2005. Managing by-catch and discards: how much progress are we making and how can we do better? Fish Fish. 6:134–155 (doi: https://doi.org/10.1111/j.1467-2979.2005.00183.x).

Harrington, J. M., R. A. Myers, and A. A. Rosenberg. 2005. Wasted fishery resources: discarded by-catch in the USA. Fish Fish. 6:350–361 (doi: https://doi.org/10.1111/j.1467-2979.2005.00201.x).

Henwood, T. A., and W. E. Stunz. 1987. Analysis of sea turtle captures and mortalities during commercial shrimp trawling. Fish. Bull. 85:813–817.

Kelleher, K. 2005. Discards in the world's marine fisheries: an update. FAO Fish. Tech. Pap. 470, 131 p.

Kumar, A. B., and G. R. Deepthi. 2006. Trawling and by-catch: Implications on marine ecosystem. Curr. Sci. India 90(7):992–931.

Magnuson, J. J., K. A. Bjorndal, W. D. DuPaul, G. L. Graham, D. W. Owens, C. H. Peterson, P. C. H. Pritchard, J. I. Richardson, G. E. Saul, and C. W. West. 1990. Decline of the sea turtles: causes and prevention. Natl. Acad. Press, Wash., D.C., 259 p.

Murawski, S., R. Brown, H. Lai, P. Rago, and L. Hendrickson. 2000. Large-scale closed areas as a fishery-management tool in temperate marine systems: the Georges Bank experience. Bull. Mar. Sci. 66:775–798.

Nance, J. M. 1993a. Effort trends for the Gulf of Mexico shrimp fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-337, 37 p.

_____ . 1993b. Review of the rock shrimp fishery off the east coast of the United States. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-324, 18 p.

_____ , W. Keithly, Jr., C. Caillouet, Jr., J. Cole, W. Gaidry, B. Gallaway, W. Griffin, R. Hart, and M. Travis. 2008. Estimation of effort, maximum sustainable yield, and maximum economic yield in the shrimp fishery of the Gulf of Mexico. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-570, 73 p.

_____ and E. Scott-Denton. 1997. By-catch in the Gulf of Mexico shrimp fishery. *In* D. A. Hancock, D. C. Smith, A. Grant, and J. P. Beumer (Editors), Developing and sustaining world fisheries resources: the state of science and management, p. 98–102. 2nd World Fish. Congr., CSIRO Publ., Collingwood, Victoria, Aus.

NMFS. 1999. Our living oceans: report on the status of U.S. living marine resources, 1999. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-41, 301 p.

_____. 2004. Evaluating bycatch: a national approach to standardized bycatch monitoring program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-66, 108 p.

_____. 2008. Sea turtle research techniques manual. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-579, 92 p. [updated 1/2009].

_____. 2017. Fisheries of the United States, 2016. U.S. Dep. Commer., NOAA Curr. Fish. Stat. No. 2016, 147 p. (avail at https://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus16/index).

NOAA. 2008. Fisheries of the Caribbean, Gulf of Mexico, and South Atlantic; shrimp fishery of the Gulf of Mexico; revisions to the allowable bycatch reduction devices. Fed. Regist. 73 FR 68355 (18 Nov. 2008), p. 68,355–68,361 (avail. at http://www.gpo.gov/fdsys/pkg/FR-2008-11-18/pdf/E8-27351.pdf).

_____. 2012. Endangered and threatened wildlife and plants; threatened and endangered status for distinct population segments of Atlantic sturgeon in the northeast region. Fed. Regist. 77 FR 5880 (6 Feb. 2012), p. 5,880–5,912 (avail. at http://www.gpo.gov/fdsys/pkg/FR-2012-02-06/pdf/2012-1946.pdf).

NRC (National Research Council). 2002. Effects of trawling and dredging on seafloor habitat. Natl. Acad. Press, Wash., D.C., 136 p.

Parsons, G., and D. Foster. 2015. Reducing by-catch in the United States Gulf of Mexico shrimp trawl fishery with an emphasis on red snapper bycatch reduction. Fish. Res. 167:210–215 (doi: https://doi.org/10.1016/j.fishres.2015.02.009f).

Patella, F. 1975. Water surface area within statistical subareas used in reporting Gulf Coast shrimp data. Mar. Fish. Rev. 37(12):22–24.

Pellegrin, G., Jr. 1982. Fish discards from the southeastern United States shrimp fishery. *In* Fish-bycatch…Bonus from the sea: a report of a technical consultation on shrimp by-catch utilization held in Georgetown, Guyana, 27–30 October 1981, p. 51–54. FAO Int. Dev. Res. Cent., Ottawa, Ont.

Price, A. B., and J. L. Gearhart. 2011. Evaluations of turtle excluder device (TED) performance in the U.S. southeast Atlantic and Gulf of Mexico skimmer trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-615, 15 p.

Pulver, J. R., E. Scott-Denton, and J. A. Williams. 2012. Characterization of the U.S. Gulf of Mexico skimmer trawl fishery based on observer coverage. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-636, 27 p.

_____, E. Scott-Denton, and J. A. Williams. 2014. Observer coverage of the 2013 Gulf of Mexico skimmer trawl fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-654, 25 p.

Raborn, S. W., B. J. Gallaway, J. G. Cole, W. J. Gazey, and K. I. Andrews. 2012. Effects of Turtle Excluder Devices (TEDs) on the by-catch of three small coastal sharks in the Gulf of Mexico penaeid shrimp fishery. N. Am. J. Fish. Manage. 32:333–345 (doi: https://doi.org/10.1080/02755947.2012.678962).

Riolo, F. 2006. A geographic information system for fisheries management in American Samoa. Environ. Modeling Software 21:1,025–1,041.

Scott-Denton, E. 2007. U.S. southeastern shrimp and reef fish resources and their management. Ph.D. Dissert., Texas A&M Univ., Coll. Sta., Tex., 400 p.

_____ and J. M. Nance. 1996. Shrimp trawl bycatch research in the U.S. Gulf of Mexico and southeastern Atlantic. *In* F. Arreguin-Sanchez, J. L. Munro, M. C. Balgos, and D. Pauly (Editors), Biology, fisheries and culture of tropical groupers and snappers, p. 360–362. Proc. EPOMEX/ICLARM Int. Workshop Trop. Snappers Groupers, Univ. Campeche, Campeche, Mex., 26–29 October 1993.

_____, P. F. Cryer, M. R. Duffy, J. P. Gocke, M. R. Harrelson, D. L. Kinsella, J. M. Nance, J. R. Pulver, R. C. Smith, and J. A. Williams. 2012. Characterization of the U.S. Gulf of Mexico and South Atlantic penaeid and rock shrimp fisheries based on observer data. Mar. Fish. Rev. 74(4):1–26.

_____, J. A. Williams, and J. R. Pulver. 2014. Observer coverage of the 2014 Gulf of Mexico skimmer trawl fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-666, 27 p.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods, 6th ed. Iowa State Univ. Press, Ames, 593 p.

Watson, J., D. Foster, A. Shah, E. Scott-Denton, S. Nichols, and J. Nance. 1999. The development of bycatch reduction technology in the southeastern United States shrimp fishery. Mar. Tech. Soc. J. 33(2):51–56 (doi: https://doi.org/10.4031/MTSJ.33.2.8).

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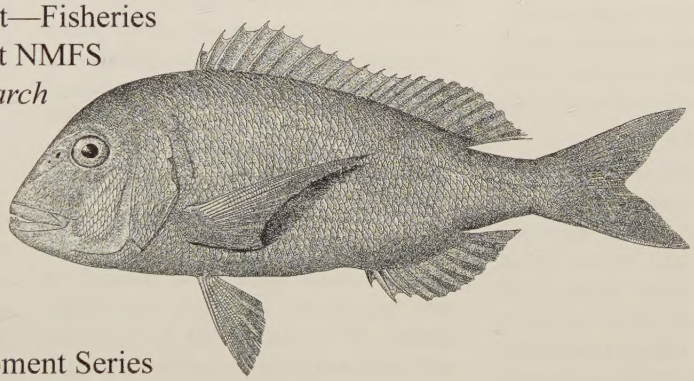

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Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

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Submission of a manuscript to the *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700 (available from the SPO website).

Manuscripts must be double-spaced throughout, and a complete manuscript normally includes a title page, a short abstract, text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

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Keep titles, headings, subheadings, and the abstract short and clear. Because abstracts are circulated by abstracting agencies, it is important that they represent the research clearly and concisely. Headings within each section must be short, reflect a logical sequence, and follow the rules of multiple subdivision (i.e., there can be no subdivision without at least two items).

Style

The entire text should be intelligible to interdisciplinary readers; therefore, all acronyms, abbreviations, and technical terms should be spelled out the first time they are mentioned. The scientific names of species must be written out the first time they are mentioned; subsequent mention of scientific names may be abbreviated. Follow the U.S. Government Printing Office Style Manual (2008 ed.) and the Scientific Style and Format: the CSE Manual for Authors, Editors, and Publishers (2014, 8th ed.) published by the Council of Science Editors.for editorial style, and the most current issue of the American Fisheries Society's Common and Scientific Names of Fishes from the United States and Canada for fish nomenclature. Only journal titles, scientific names (genera and species), and vessel names should be italicized. Dates should be written as follows: 11 November 2013. Measurements should be expressed in metric units, e.g., metric tons as (t); other equivalent units may also be listed in parenthesis. Common abbreviations and symbols such as mm, m, g. ml, mg, and °C (without periods) may be used with numerals. The numeral one (1) should be typed as a one, not as a lower-case el (l). Write out the numbers zero through nine unless they form part of measurement units (e.g., nine fish but 9 mm).

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Tables should be printed separately and double-spaced. Tables should not be excessive in size and must be cited in numerical order in the text. Headings should be short but ample enough to allow the table to be intelligible on its own. All unusual symbols must be explained in the table heading. Other incidental comments may be footnoted with Arabic numerals. Because tables are typeset, they need only be submitted typed and formatted, with double-spaced legends. Zeros should precede all decimal points for values less than one. Table headings and format should be consistent; do not use vertical rules.

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Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1979a, 1979b, 1979c, etc.). Authors must double-check all literature cited; they alone are responsible for its accuracy.

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